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NASA-TM-83099

NASA Technical Memorandum 83099

NASA-TM-83099 19860007795

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1985 ANNUAL REPORT

John F. Kennedy
Space Center

Research and Technology 1985 Annual Report of the John F. Kennedy Space Center

N86-17265 #

FOREWORD

As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safer, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to the Space Station and other future programs. The Engineering Development Directorate encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation, and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1985 Annual Report. The report contains brief descriptions of research and technology projects in major areas of Kennedy Space Center's disciplinary expertise.

For further technical information about the projects, contact David A. Springer, Project Engineering Office, DF-PEO, (305) 867-3035. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Center-wide research and technology program.

A handwritten signature in black ink, appearing to read "R G Smith".

Richard G. Smith
Director

AVAILABILITY INFORMATION

For additional information on any summary, contact the individual identified with the highlight. Commercial telephone users may dial the listed extension preceded by area code 305. Telephone users with access to the Federal Telecommunications System may dial the extension preceded by 823.

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INSTRUMENTATION AND HAZARDOUS GAS

Hazardous Gas Detection System Sample Line Transport Time Study

The use of large quantities of explosive and toxic propellants at Shuttle launch and landing sites necessitates the use of a number of gas detection sensors and systems. These draw samples through lines that range from a few to several hundred feet in length. While NASA has expended considerable effort to collect and publish a handbook for the designer of high-pressure gas systems, the designer of gas sampling systems is forced to calculate from first principles for each new problem.

In this study, an analytical model of sample lines has been developed which uses coefficients obtained from laboratory tests of short lengths of various size tubing, ranging in diameter from $\frac{1}{8}$ to $\frac{3}{8}$ in.

At present, tests of 200 and 400-ft lengths of the optimum size sample line are being conducted to compare with the analytical model.

W. Helms, 867-4478
P. J. Welch, 867-4614

DL-NED-31,
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Remote Sensing of Hydrazine

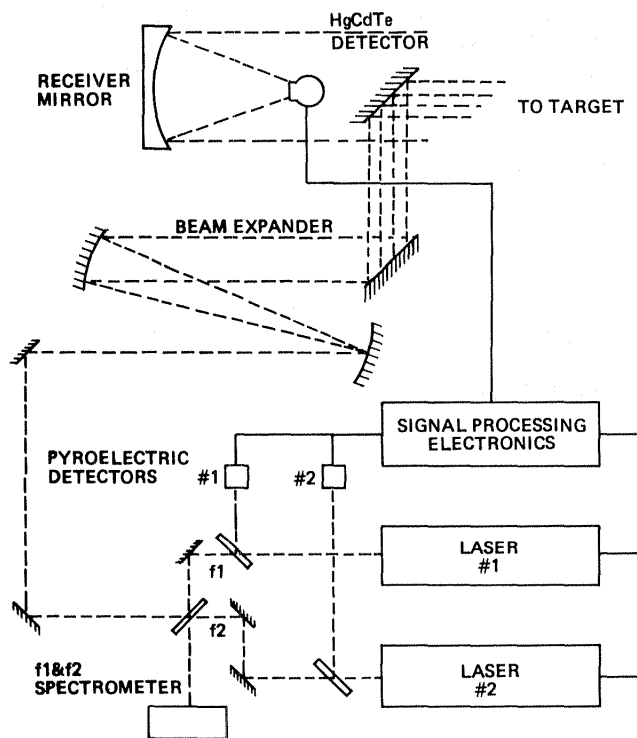
A Laser Remote Sensing Instrument has been fabricated and delivered to the Kennedy Space Center (KSC) by the Jet Propulsion Laboratory (JPL). The JPL performed the research that determined the instrument design at the initial phase of this project. In the next phase, JPL fabricated and tested the instrument to verify the concept. This prototype system is designed for the detection of hydrazine, monomethylhydrazine, unsymmetrical dimethylhydrazine, and ammonia remotely to a distance of 250 meters. The key elements of the system are a pair of rf-excited, grating-tuned waveguide CO₂ lasers, a beam expander, a f/1 receiver mirror, a mercury-cadmium-tellurium (HgCdTe) detector and signal processing electronics.

The instrument indicated in the figure, "Laser Remote Sensing System" uses the Differential Absorption Lidar (DIAL) technique for detecting

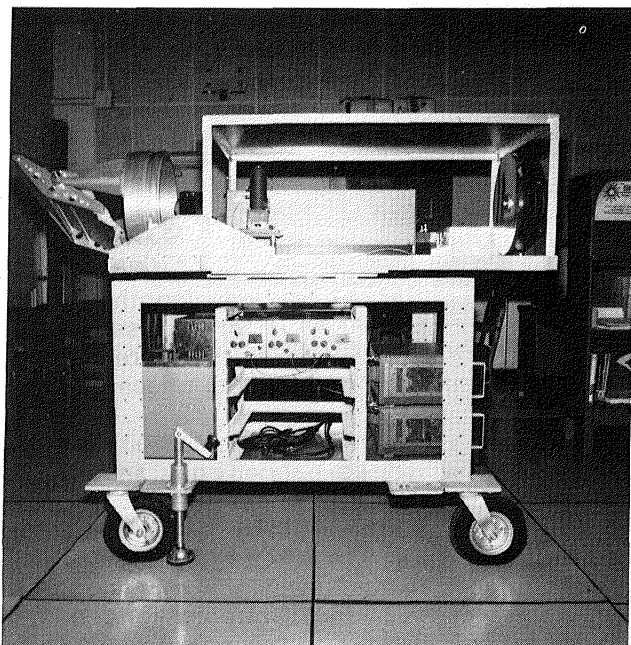
the vapors. Each laser is tuned to the appropriate set of wavelengths — one at the wavelength that the vapor of interest absorbs the infrared (IR) energy and the other one to a wavelength that is close to the first, but will be absorbed less by the vapor. These pair of wavelengths were determined by JPL during the research phase of this effort.

The two laser beams then are combined into a single beam which is expanded and transmitted to a target which will reflect the IR energy (asphalt, trees, and the like). The reflected beam received back is focused into a HgCdTe detector, which produces an electrical signal that is amplified and processed by the electronics for display. The electronics determine the concentration of the vapor by separating the received signal into the original laser signals and taking the ratio of the two signals, which gives a concentration-pathlength result.

KSC will continue the development of the system in the area of automated control and signal processing electronics. Tuning of the lasers to the desired wavelength and verification that each



Laser Remote Sensing System



Remote Sensing of Hydrazine Instrument

laser is tuned properly will be done under computer control. The computer will also control the modulation of each laser, monitor the laser output, and process the received signal for the data display. Additional instrumentation will be added to the system so that the lasers can be maintained at the proper operating temperature by the computer, as well as supply additional data during field testing at KSC, such as ambient temperature, relative humidity, and atmospheric pressure.

M. M. Scott, Jr. and P. M. Rogers, 867-3086
DL-DED-32

Advanced Hazardous Gas Detection System

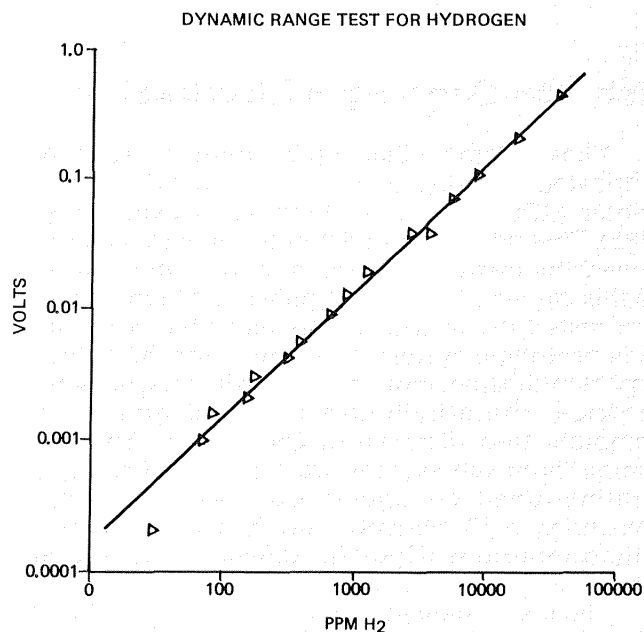
Objective: The objective is to develop a prototype detector for gaseous propellants used aboard the Space Shuttle. The prototype will be based on the proven Navy Central Atmosphere Monitoring (CAMS) hardware. It is not the intent of this portion of the project to produce a complete system to replace the current Hazardous Gas Detection System (HGDS), but to prove that the CAMS analyzer will meet and exceed the performance and reliability specifications required of the HGDS.

Background: Prior to launch, various compartments of the Shuttle are monitored for

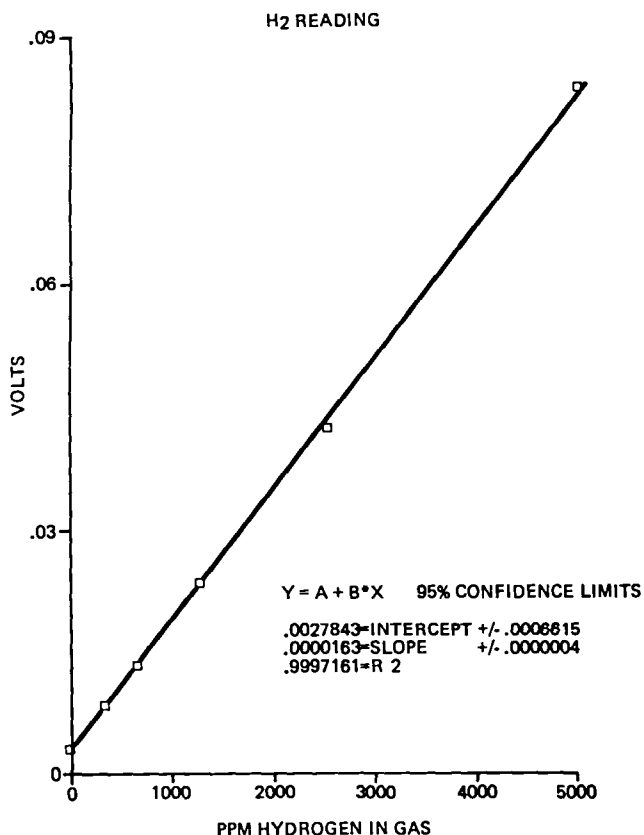
hydrogen, oxygen, and helium leaks. The Naval Research Laboratory (NRL) was selected by NASA to adapt the CAMS to monitor these gases. CAMS is used aboard all nuclear submarines and has a Mean Time Between Failure (MTBF) greater than 3,000 hr when operated continuously in a submarine environment. It does not require recalibration during its 20,000 hr of average use between refurbishments. Approximately 40 CAMS analyzers are being refurbished every year. The expertise to refurbish the unit and obtain spare parts is being maintained and will continue to be maintained by the Navy in the future.

Approach: The mass spectrometer module of the CAMS has been modified to detect helium and argon, in addition to hydrogen, nitrogen, and oxygen. Where possible, the CAMS mechanical and electrical hardware were used. For testing and evaluation, the analyzer was interfaced to a commercial microcomputer system. The detection limits, dynamic range, accuracy, and long-term stability have been measured.

During the six months of testing at NRL, the system had only one minor problem which did not prevent it from measuring the required gases. This problem — the failure of the automatic leak valve control — required a minor adjustment of the leak valve about once a week. The figure, "H₂ Dynamic Range" shows the signal for hydrogen as a function of the hydrogen concentration in the inlet gas stream. The system is linear from less than 100 parts per million (ppm) to more than 30,000 ppm of hydrogen. No range or gain changes in the AHGDS were neces-



H₂ Dynamic Range



H₂ Linearity

sary for this experiment. In general, the AHGDS could measure gas concentrations to better than 1 percent of actual concentration. The figure, "H₂ Linearity" shows the measurement for hydrogen in the critical range for detecting leaks.

The long-term stability of the AHGDS was tested by continuously sampling a gas cylinder containing 1000 ppm each of hydrogen, helium, oxygen, and argon in nitrogen. No adjustments or calibrations were made to the system during three months of continuous testing. An accuracy of ± 5 percent of measurement range was maintained over this period.

J. D. Collins and W. Helms, 867-4438
 DL-NED-32

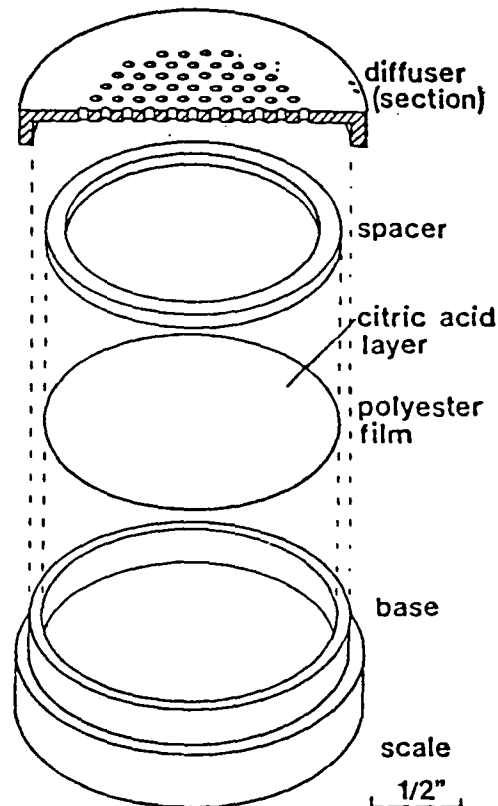
Hydrazine Personal Dosimetry

Objective: The objective is to develop a dosimeter system capable of measuring hydrazine and monomethylhydrazine (MMH) at a dose rate of 100 parts per billion (ppb)/hour. In particular, passive systems that could be worn by individuals will be investigated.

Background: Space Shuttle operations often require that a large number of personnel work in areas where the possibility of hydrazine leaks and spills exists. In the event of a hydrazine release, it is desirable to be able to determine the exposure of affected personnel. Currently, no suitable technology exists for this task. Recent studies of an experimental badge manufactured by GMD Systems, Inc. indicate that use of a passive sampling, liquid-sorbent badge for a dosimeter may be feasible, although it lacks the necessary precision.

Approach: Available commercial and experimental dosimeter badges will be investigated. Performance will be determined in terms of lowest detection limit, accuracy, specificity, and long-term behavior. Both laboratory testing at NRL and field testing at Kennedy Space Center (KSC) will be conducted. Different membranes, liquids, and solid-sorbent materials will be evaluated. Appropriate analytical techniques for the different sorbents will also be developed.

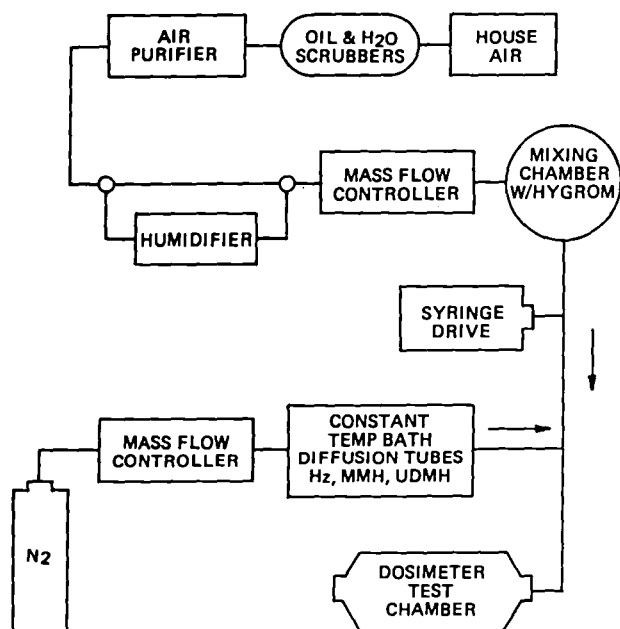
A new passive dosimeter has been developed for determining ppb levels of MMH propellants in air as shown in the figure, "Dosimeter." The lightweight design can be worn either as a personal or an area monitor for time-weighted averages. The badge uses a diffuser cap and an organic acid collection medium, which can be analyzed using



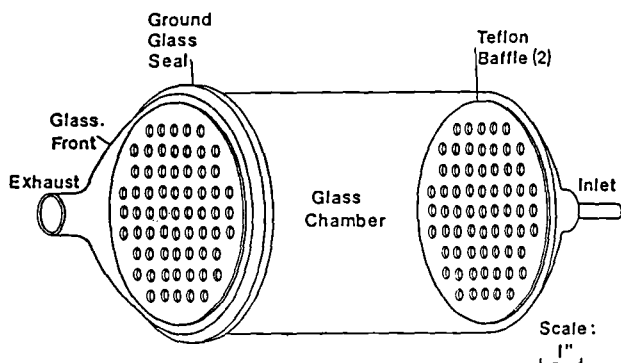
Dosimeter

either a NIOSH colorimetric method or a coulometric titration. The badges have been tested using the apparatus in the figure "Test Apparatus." The chamber in the figure, "Dosimeter Test Chamber" provides laminar flow at known face velocities. The badge samples at a rate of 30 ml/min, with accuracy of better than 20 percent. The dosimeter has demonstrated accuracy for up to 65 hr of sampling and the MMH is stable in the collection medium for more than seven days. The detection limit is less than 50 ppb/hr. Results show good linearity, minimal relative humidity effects, no interference effects from ammonia, freons, or alcohols, and no face velocity effects between 2 and 20 ft/min.

J. C. Travis and W. Helms, 867-4438
DL-NED-32



Test Apparatus



Dosimeter Test Chamber

Evaluation of Hydrazine Detectors Based upon Emerging Technology

Objective: To test and evaluate technologies suitable for monitoring hydrazine at the parts-per-billion (ppb) level. The three promising technologies are: 1) chemically doped paper tape, 2) chemical derivation followed by chemiluminescent detection, and 3) photoionization.

Background: Results of the Phase I evaluation of hydrazine detectors demonstrated that none of the existing technologies for hydrazine detection meets NASA objectives for reliability, stability, and selectivity. Therefore, new, yet unproven, technologies will be investigated to determine if a suitable instrument based upon them can be developed.

Approach: Three technologies will be investigated:

1. Chemically-doped paper tape. The results of a test and evaluation of commercially available instruments showed that paper tapes were capable of selectively determining hydrazine at the ppb level, although the performance of the associated instrumentation was inadequate. Two new instruments utilizing an improved tape-transport mechanism are being studied to determine its potential. Both the MDA 7100 fixed point monitor and the GMD systems Autostep are showing much promise. The response times are approximately 6-8 min to 90 percent of the full scale responses. The linearity of the responses is good and the instruments appear to be reliable.

2. Chemiluminescent. A method of sampling hydrazine by first reacting it with acetaldehyde, then detecting the reaction product, has been developed by Thermo Electron Corp (Thermedics). Extensive studies with hydrazine and monomethylhydrazine have shown that the instrument possesses excellent linearity and accuracy and has adequate sensitivity. The Thermedics instrument is linear over tested concentration range of .020-2 ppm, and has an accuracy of 20 percent. The instrument has had several problems that have affected the reliability. Many of the problems that have been revealed through this evaluation can be removed by careful engineering. This technique will be studied to determine if it would be a suitable fixed-point monitor, and whether or not a portable instrument could be constructed using a portable chemiluminescent NO detector.

3. Photoionization. Photoionization appears to be a selective method for hydrazine detection due to the low ionization potential of hydrazine. Preliminary work with hydrazine and MMH has shown that the technique possesses the necessary sensitivity and dynamic range. In addition, this method appears particularly attractive for use in space

operations. A portable photoionization detector will be modified and evaluated for use as a hydrazine detector.

J. C. Travis and W. Helms, 867-4438
DL-NED-32

Pattern Recognition Methods for Toxic Vapor Detection Using Microsensors

Objective: The objective is to develop a microsensor array capable of measuring hydrazine at the parts per billion (ppb) level.

Background: Personnel safety requires hydrazine vapor detection at ppb levels. The commercially available instruments cannot reliably detect hydrazine, monomethylhydrazine, and unsymmetrical dimethylhydrazine at the National Institute of Occupational Safety and Health (NIOSH) recommended values of 30, 40, and 60 ppb.

Major advances have been made in microsensor technology and pattern recognition techniques that could improve hydrazine detection. Novel chemical microsensors (chemiresistors) are being developed by the Naval Research Laboratory for the detection of chemical vapors. Chemiresistors (see the figure, Chemiresistor System) change resistance when exposed to different compounds. The magnitude of the change depends on the interaction of the gas vapor with the coating on the microsensor.

Approach: Microsensors are being coated with materials that will respond to different chemical classes of compounds in a complex air mixture. In addition, attempts will be made to develop a specific hydrazine coating. An array of these sensors gives unique patterns or fingerprints, describing the substances present.

Interpretation of the fingerprints produced by the array of sensors is being analyzed, using pattern recognition methodology. These methods use modern mathematical techniques of multivariate statistics and numerical analysis to improve the measurement process, as well as extract more chemical information. In order to apply pattern recognition techniques to microsensor array data, these following four premises are necessary:

1. The compounds and the microsensor response must be related.
2. The compounds can be adequately represented as a set of microsensor responses.

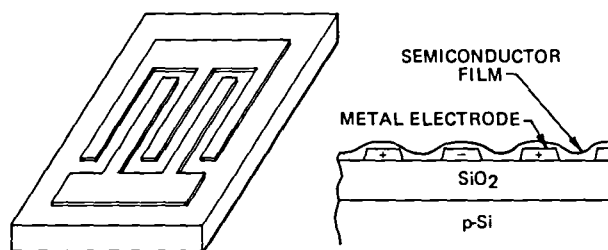
3. A relation can be discovered between compound and response by applying pattern recognition methods to a set of tested compound mixtures.
4. The relation can be extrapolated to untested mixtures.

Each compound can be thought of as a point whose position in space is defined by the values of each chemiresistor response. Similar objects tend to cluster in a space defined by their sensor responses. Pattern recognition is a set of methods for investigating the clusters in space.

A total of 42 gas vapors were exposed to the chemiresistor array, 18 containing hydrazine and 24 without hydrazine. Twenty-two pure compounds and 20 mixtures in air were represented. The fingerprints produced by the microsensors are being analyzed using several different methods showing some clustering. Training routines show 81 percent correct classification of hydrazine, even in the presence of other compounds. The misclassified compounds were nitrogen-containing compounds. This suggests coatings are needed to identify nitrogen environments.

The classification of the compounds into the appropriate classes will be achieved by selecting the proper microsensor coating to form the individual clusters. Through the use of computers and mathematical and statistical methods, the data of interest will be extracted from a complex background. The goal is to quantitate this information and make progress toward the design of an intelligent detector.

J. D. Collins and W. Helms, 867-4438
DL-NED-32



Chemiresistor System

Remote Detection of the Burning GH_2 Plume from the Shuttle Centaur Vent

Purpose: The purpose of this study was to determine whether currently available portable flame detectors were suitable for the long-range (up to 1000 ft) detection of the H_2 vent plume from the Shuttle Centaur vent.

Background: In the event of an aborted launch of a Shuttle Centaur mission, the Shuttle would be forced to land with as much as 50 lb of liquid hydrogen still onboard. As the liquid hydrogen boils off, it builds up pressure, and at a given level, it is vented through a relief valve to the atmosphere. The proximity of the relief valve to the hot Auxiliary Power Unit exhaust is expected to result in ignition of the hydrogen plume, which may extend 60 ft. In order to protect the ground crew, it is necessary to identify the hydrogen plume and determine its size, direction, frequency, duration, and whether or not it has been ignited.

Approach: Two instruments were available for evaluation. These were the Omegascope 2000A-S and the Detronics U7606. The Omegascope is an IR detector (8-14 micron range) with approximately a 2° field of vision, digital readout in $^\circ\text{C}$ or $^\circ\text{F}$, and variable, manually controlled emissivity setting. The Detronics is a UV detector (.185-.245 micron range) with a 160° field and audible output in the form of one click per photon. The Detronics instrument has a relatively insensitive analog readout, which was not used for these tests.

Since no data was available at the time of the first test regarding the emissivity of the hydrogen flame, the Omegascope emissivity control was arbitrarily set at 50 percent. This resulted in a temperature reading of 334°F when aimed at a 10-in H_2 flame from a distance of 6 to 12 in.

Both instruments responded well to the 10-in. flame at short range. However, as the distance increased, the response decreased by the inverse square of the distance. The Omegascope IR detector was unable to distinguish flame from background at approximately 35 to 40 ft. The Detronics UV detector was able to respond at a distance of 65 to 80 ft.

The table below presents comparative data using the Omegascope 2000A-S and the Detronics U7606 in a side-by-side test. This test was conducted under the conditions stated above and a clear-sky background reading of 62°F . For the purpose of this test, the accuracy of the temperature readings on the Omegascope were not relevant. The object was to identify a flame relative to background readings, not to characterize the flame.

Distance (ft.)	Omega- scope (Avg. $^\circ\text{F}$)	Detronics (audio pulse response)
12	129	Rapid
20	89	Rapid
25	80	Rapid
30	71	Steady
35	69	Steady
40	70	Steady
50	Ambient	≈ 60 pulses/min
55	Ambient	≈ 40 pulses/min
60	Ambient	≈ 20 pulses/min
65	Ambient	≈ 15 pulses/min
80	Ambient	Random
100	Ambient	Random

Conclusion: The principal difference between the two instruments is that the UV detector reads a genuine zero (no audible output) when no flame is in the field of view, while the IR detector reads the ambient sky temperature, and likely would be damaged if pointed at the sun. This is a distinct difference, which seems to favor the UV detector, since there is little dependence on operator judgment in the interpretation of the UV detector response.

Note: A subsequent requirement to characterize the flame produced by the Pad B Hydrogen Flare Stack at Kennedy Space Center (KSC) provided additional information. Data from the Flare Stack Flame Characterization will be reported separately, but conclusions relative to this report indicate the following:

The Detronics UV detector gave an indication from the stack pilot (a 2-to 3-ft. propane flame) from a distance of about 1500 ft., indicating acceptable sensitivity at this distance. However, the wide field of view, 160° , may lead to interference from extraneous sources. From a distance of 500 ft., the Omegascope field of view was sufficiently filled to obtain reasonable temperature data and easily identified the 60- to 100-ft. H_2 plume.

If the hydrogen plume is not ignited, an alternate method of detection will be required. To optimize remote detection of the Shuttle-Centaur H_2 vent plume, it is recommended that a small telescope be equipped with a UV and/or IR detector. This would serve to narrow the field of vision and minimize extraneous interference, extend the range, and provide optical imaging to observe the change in refractive index, in the event the H_2 does not ignite.

J. C. Travis, 867-4438

DL-NED-32

LIQUID LEVEL DETECTION AND FLOWMETERS

Optical Fiber Vortex Shedding Flowmeter

In flowmetering systems where minimum pressure drops due to the metering devices are important, vortex shedding flowmeters using fibers as the shedder bar seem to have great promise. If the fibers are of small dimensions and looped properly (not too tightly stretched across the flow path), they will oscillate in phase with the vortices shedded by them.

If these fibers are at the same time optical fibers of the multimode type, they produce a speckle pattern when coherent light is passed through them. This characteristic speckle pattern is stationary as long as the fiber is unperturbed. When the fiber, or any portion of the fiber is vibrated, the speckle pattern will vibrate at the same frequency. The coherent light is produced by a laser, and the resulting speckle pattern is projected upon a photocollector which produces a voltage, oscillating with the same frequency as the fiber. The fiber frequency, as in conventional vortex shedding meters, is proportional to the flow rate.

In the work reported upon here, a Lexel Model 95 Argon Ion Laser was used at low power (approximately 0.1 watt) to provide the coherent light. The beam was focused through a convergent lens and coupled into the fiber. The output of the fiber and coupled photocollector were sent in parallel to a 10 MHz storage oscilloscope, a data recorder, a third octave sound and vibration analyzer, and a frequency spectrum analyzer.

To prove the feasibility of using this method for flowmetering, the fibers were mounted on a shaker table and vibrated at predetermined frequencies. The output under those conditions was analyzed and calibration obtained. When this phase of the investigation was judged successful, a flow loop was built and the fibers mounted in the loop simulating the conditions encountered in hypergolic flows.

The fiber sizes used ranged from 250 μ m to 500 μ m, and were from 0.5 to 3 ft. long. All fibers were prepared in the same manner as described in detail above.

The beam from the laser source was split to have a reference and a sensor beam, which was guided through the vibrating fiber. This procedure allowed the subtracting out of any background and extraneous signals.

Several test sections and different fiber sizes

and configurations were prepared and then experimentally investigated. As many theoretical predictions as possible were made.

It was found that the optical fibers shedded vortices and vibrated in phase with the pressure pulses produced. For one fiber configuration, it was found that two or three response frequency peaks were produced, each appearing with maximum amplitude in a different flow range. As an example with test section 2, at 0.4 gpm in a 1/2-in. diameter section, the peak of maximum amplitude gave a frequency of 82.5 Hz. This peak, however, almost disappeared when the flow was increased to 1.1 or 1.5 gpm, but still resulting in a frequency of 152 Hz. However, some time before the amplitude of the first frequency peak became low, a second peak of higher frequency of oscillation appeared, for instance, giving 215 Hz at 1.12 gpm. The amplitude of the second peak declined at about 3.9 gpm, giving an oscillating frequency of 305 Hz. But at that condition, a third peak had appeared with higher amplitude and could be used for measurements. At 2.59 gpm, the second peak response frequency was 270 Hz, while the response frequency of the third peak was 520 Hz.

From the data obtained with this flowmetering system, it seems that the method can measure flow accurately and satisfactorily over the required range. The instrumentation is, however, more complicated, delicate, and expensive than the previously described vortex shedder flowmeters.

Also investigated was the effect of particulates in the fluid. The effect of these solid particles impinging upon the optical fibers had the result of reducing and the oscillating frequency, thus altering the calibration. Filters in the line can minimize this effect.

The frequency response peaks were very sharp and the frequency of oscillation can be measured quite accurately. The temperature of the flowing fluids were changed from 24°C to 44°C; a change in frequency was observed. From theoretical analysis, it seems that the variation is due to viscosity changes of the fluid.

Thus, it seems that with the proper fiber configuration to allow several modes of vibration, resulting in several frequency peaks each having its best range of responses and accuracy, a reliable flowmeter can be developed having no moving parts, good rangeability and accuracy, as well as negligible pressure losses.

The attachment of bluff bodies to the optical

fibers to give them specific vortex shedding characteristics, could be a worthwhile project for future investigations.

B. Howard, 867-3366

DL-DED-31

Flowmetering — Using Vortex-Shedding Instrumentation

The objective of this investigation was to develop a ½-in. flowmeter for cryogenic or other fluids which uses the vortex shedding principle.

The literature review and patent search revealed a great number of shedder bar flowmeters of varied designs, each having certain characteristics. Many different shapes and combinations of shedder bars have been used. A number of such flowmeters were found unuseable under cryogenic temperature conditions.

The best design seemed to be an edged shedder bar with Piezoelectric crystal pick-up located at the end of pressure ports.

At this point, it was decided to go to experimental studies of the "Optimum Shedder Bar Shape" and "Best Pressure Tap Location and Size."

A water table was constructed and set up to visualize the vortex motion around different shedder bar shapes and the travel of these vortexes toward the walls. Also, an air wind tunnel was set up to make similar investigations, but by using anemometer probes to determine the action of the vortexes and the best positions of measuring the pressure pulses.

A water loop also was constructed where actual measurements for flow rate and total flow measurement were taken and the best designs of the flowmeters evaluated. A similar flow system was set up using LN₂ as the cryogenic fluid to measure flow rates and total flow under those environmental conditions.

From the experimental studies, guided by the theoretical work, it was found that:

1. The square- or diamond-shaped shedder bar facing the fluid edgewise gave the strongest and cleanest signals. This shape does not seem to be patented.
2. The pressure tap-hole was ⅛ in. and located at the pipe wall at the centerline position of the shedder bar.
3. The pressure pulses were, for example, at 1.7 gpm, 70 per sec, and 0.06 psi peak-to-peak. At 3.58 gpm, the corresponding values were 215 counts per sec, and 0.6 psi.

4. The counts (pressure pulses) per second, varied linearly with the flow rate.
5. The total flow was proportional to the total count or number of pressure pulses.
6. Only the frequency of pulses, and not the wavelength of the vortexes, changed with the change in flow rate. Thus, once the optimum pressure tap position was found, it remained the same for the total flow range.
7. The flowmeter measured flow rates to within ±2 percent.
8. The flowmeter could also be used as a two-phase flow sensor, since it has worked nicely in liquid cryogenics, but has stopped oscillating or vortex shedding in two-phase flows.

B. Howard, 867-3366

DL-DED-31

Gamma Ray Densitometer Liquid Level Instrumentation

The gamma ray densitometer essentially consists of a radioactive source (very weak for the application under consideration here) and a detector system measuring the radiation intensity at desired locations. The radiation beam is weakened by the intervening material. From the absorption characteristics of the materials, the quantity of matter and liquids in this particular investigation can be determined.

In this investigation, a suppressor tube was developed so that in turbulent systems, even when mixing vapors with liquids, the true liquid level can be determined.

A small, radioactive source encapsulated and attached to a float can be put inside a tank, restrained by the collapser tube, and will float, indicating the surface of the liquid in the tank. Radiation detectors mounted on the outside of the tank then can be placed at the top, bottom, or side of the tank. The weakened count will give the position of the floating source and, thus, the liquid level in the tank.

In a cylindrical tank, a straight suppressor tube can be used in the middle or on the side of the tank; in a spherical or other-shaped tank, the collapser tube can be attached to the wall, having the same contour as the wall.

The detector can be fixed in position or can be of the scanning type, depending upon convenience in a particular application. Even several different sources and detectors can be used to give easily interpretable information in three dimensions.

The information obtained this way can be fed into a computer, which can display a simulated tank and show the position of the float and liquid level at all times. This method was demonstrated to the NASA personnel during one of their visits.

A number of different detector configurations are discussed below, and the results and accuracy given. The liquid levels could certainly be fixed within 1cm (or better, as shown below) of actual position, using the gamma ray densitometer instrumentation. Lengthening the counting time or increasing the source strength for the same counting time would naturally improve the accuracy. For this investigation, very weak radiation sources were used which could easily and safely be carried in one's pocket.

Theoretically predicted results were closely verified by the experimental work. The configurations used in the present investigation included cylindrical tanks with the axis both vertical and horizontal, and a spherical tank. The detectors were located, in some cases, on top of the tank, on the bottom, or both. For other experiments, the detectors were located on the side of the tank, either fixed or in a scanning mode.

If it should be desirable not to have any sources inside the tanks, a collimated source could be located on one side (top or bottom) of the tank and the detector can be placed on the opposite side of the tank, again measuring the weakening of the beam as it traverses the contents of the tank.

As an example, the 1-sec counts with an AM241, 300mC source, and a water liquid level of 5 cm varied for the bottom detector at a count rate of 140,766, about 3,000 counts for each millimeter of liquid level change.

The reproducibility of experiments with a $1.1\mu\text{C}$ Cs 137 source fell well within 2 percent of each other. The increase in counting time, if quick response and instantaneous readings are not required as mentioned above, will increase the accuracy of determination and can reduce the required strength of the source needed.

Another approach using the gamma ray densitometer not investigated under the present contract would be to make the liquid level and liquid inventory determination by relying upon the information from back-scattered gamma rays.

B. Howard, 867-3366

DL-DED-31

Liquid Characteristics Under Micro-Gravity Conditions

In space, under micro- or zero-gravity conditions, liquids will behave differently. Top and bottom of tank notation will lose their meaning and there will be no guarantee that the outlets of tanks will be covered by liquid which is so necessary for liquid-transfer operations. Ingestion of vapor into pumping systems is a very likely occurrence during liquid transfer under such environmental conditions.

Dynamic effects, in conjunction with liquid surface curvature produced by surface tension, can be exaggerated in low-gravity fields. Very little information could be found in the literature, especially after 1970. Many questions on the behavior of liquids under the above mentioned environmental conditions do not seem to have been answered thus far.

Theoretical investigations give some information about behavioral trends. Experimental investigations, mostly done by NASA in drop tower tests, support the fact that surface tension is an important parameter, if not the most important one, in controlling the behavior of liquids in low-gravity fields. Drop tower tests are expensive, short in duration, and need to be done in a facility.

The investigation team working on this project thought it might be possible to simulate the behavior of liquids in low-gravity fields by immiscible liquids having a clearly defined interface, but otherwise equal specific gravity. Some preliminary experimentation was done.

An even more promising approach using soap films or bubbles to simulate the interface between two liquids was developed using air in the cases investigated here. By pulling a vacuum on one side of the soap film, the soap film seems to take on the configuration of the liquid vapor interface similar to actual conditions. The last statement is based upon preliminary tests and comparisons with the drop tower results reported by NASA.

The simple and inexpensive laboratory simulation techniques developed here and preliminary test results seem to indicate that this powerful method can be used in investigating the behavior of liquids in low-gravity environments, especially during liquid transfer, and can be used in designing proper or optimum configurations, as well as defining proper transfer procedures of liquids under those conditions.

B. Howard, 867-3366

DL-DED-31

FIBER OPTICS

Fiber Optic Terminal Equipment Development

Kennedy Space Center (KSC) currently is in the process of developing a new generation of fiber optic terminal equipment to meet the ever-changing communications requirements of the Space Transportation System. Shuttle payload requirements, coupled with future Space Station requirements, have created the need for a modular, flexible, and expandable terminal equipment system.

The current development effort is intended to design and test a prototype fiber optic communication system which will support current requirements and be capable of expanding to meet new requirements.

The terminal equipment is being designed using a modular concept to allow easy replacement and/or upgrading of system components, without replacing the entire system.

The optical transmitter module can be configured to transmit wideband analog data, 5 Hz to 5 MHz; baseband video; low-speed digital data, 1 to 4 Mbps; or high-speed digital data, up to 500 Mbps. To transmit baseband video signals, for example, the transmitter module will consist of the following four cards:

1. User Interface Card: Provides buffered interface between the user signals and the rest of the transmitter module. This card will accept single-ended and differential input signals. It can be adjusted to accept various input levels, impedances, and cable types, and provide a constant output to the rest of the transmitter module. It allows the Control Card to monitor and control its function.
2. Modulator Card: Converts a baseband video or analog signal into a digital FM signal to improve the signal-to-noise ratio. This card has several functions which may be monitored or controlled by the Control Card.
3. Optical Transmitter Card: Converts the electrical signals into optical signals for transmission over fiber optics. This card currently uses 1300 nm laser. Lasers at other wavelengths could easily replace it. A Light Emitting Diode (LED) transmitter also could be used in the system for driving shorter cable length.
4. Control Card: This is a microprocessor-based

monitor and control card which reports module health to a supervisor system. This card consists of a microprocessor, Random Access Memory (RAM), Read-Only Memory (ROM), digital inputs, digital outputs, analog inputs, analog outputs, a front panel interface, and a RS-485 serial interface. The control card is connected to all the other cards in the module via a 60-pin cable. This card also interfaces with the module front panel which allows local setup, monitor, and control of most of the module's functions.

The transmitter module is mounted in a chassis with up to four other modules. The other modules will be physically configured in a similar fashion.

The Supervisor module can occupy one of the chassis slots, providing monitor and control functions for up to 128 other modules. The Supervisor module can, in turn, communicate with a central office computer to accept commands for the various modules and report back their status.

This supervisory architecture allows the central office to monitor the active links and rapidly respond to any problems. When the system is used in conjunction with a remote controlled data switch, the central office computer can monitor that system's performance, identify problems, reroute signals around problem hardware, notify operators of a failure, issue trouble reports, and generate a data base of hardware failure information.

The flexibility of this approach will allow rapid equipment reconfiguration to meet new requirements, while minimizing the maintenance and operation costs.

This project has already produced working prototypes of transmitter and receiver modules interfaced with a personal computer, acting as the Supervisor module. The transmitter, receiver cards, and a digital bit-sync card were fabricated by Martin Marietta Corporation for NASA. After the development and testing phase is completed, KSC will produce specifications and production drawings.

This documentation will be sufficiently detailed to allow NASA to competitively bid a contract for fabrication of this equipment to meet future wideband communications requirements.

M. E. Padgett, 867-3367

DL-NED-12A

FLUIDS, GASES, AND MECHANISMS

Collapsible Air Lock

During entry and exit of payload canister transporters (and occasional other vehicular traffic) into and from the O&C Building, an air lock for the Easy High Bay door would prevent loss of HVAC, increase in relative humidity, and particulate contamination introduced by the payload canister transporter.

A conceptual design study indicates the feasibility of erecting a collapsible, transportable air lock comprising two telescoping vinyl nylon enclosures. Rollup doors on both the east and the west ends of the air lock will allow its use as a mobile air lock. Portable air-conditioning units with filters will provide clean air and positive pressure to the inside of the air lock until particulate measurement indicates that the ambient air and the canister transporter are at acceptable levels of cleanliness for entry into the O&C. The periodic increase of internal pressure which will occur when clogged HEPA filters are replaced by clean filters can be relieved by opening selected fabric panels to the atmosphere. In practice, the skirt around the bottom under the longeron beam will probably leak sufficiently to be self-relieving.

The collapsible feature will be accomplished by telescoping the inner section [reducing the length of the air lock from 80 ft. (extended) to 40 ft. (collapsed)]. The entire structure, permanently mounted on eight dual, rubber-tired wheel

assemblies, can then be moved into the O&C for protection from the elements.

The entire air lock can be disassembled and packaged for airlift to a contingency landing site on a single C-141 airplane. A second C-141 would be required for the two 30-ton, 11,000 cfm air-conditioning units and ancillary equipment.

The figure below displays significant features of the air lock.

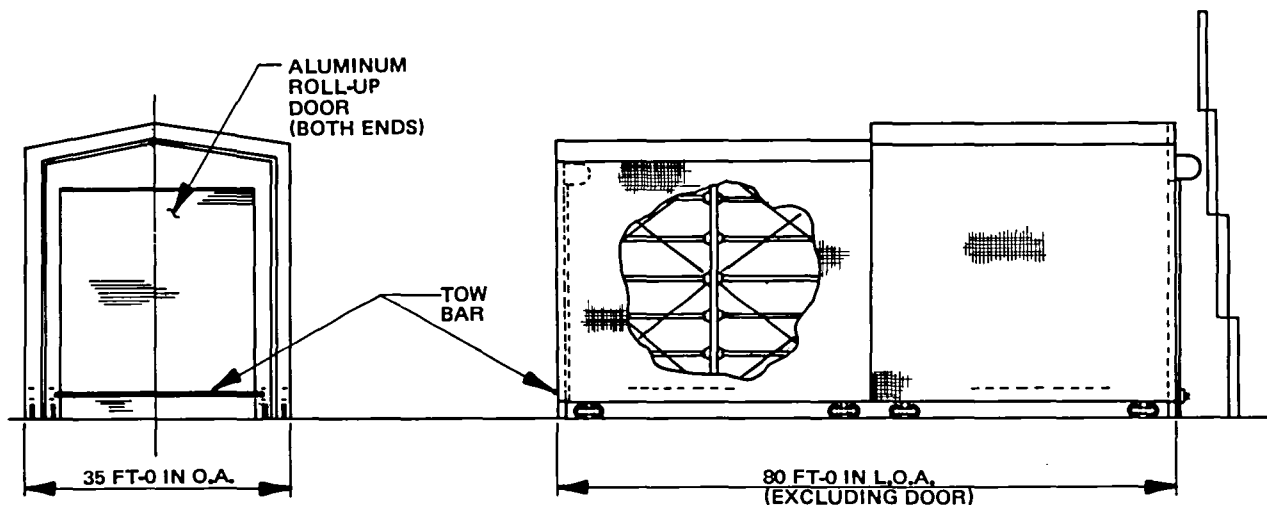
T. LaMontagne, 867-4454

SI-FSO-3

Effectiveness of Non-Recirculating Air Curtains on Contaminants Control

The history of air curtains can be dated back to the turn of the century. In 1904, Theophilus Van Kennel applied for a patent on a device which blew air from both sides of an entrance to counteract wind forces and seal the entrance from outside air. The device appears to be the forerunner of the modern air curtain.

During the past three or four decades, air curtains have been widely used in some industrial establishments to minimize the transfer of heat, moisture, and contaminants through openings



Collapsible Air Lock

separating different environments. They also have been used for insect control in food processing plants, bottling plants, restaurants, and supermarkets.

There are two major types of air curtains — recirculating and non-recirculating. The recirculating air curtains emit air from a discharge grille on one side of the door opening, collect the air through a receiving grille on the opposite side, and return the air through ductwork to the discharge grille. These types of air curtains mainly are used in restaurants, supermarkets, and other public buildings. To avoid objectionably high air speeds on pedestrian traffic, the air speeds are usually less than 1,500 ft./min. To achieve adequate stiffness, the thickness of the jet must be 2 to 3 ft.

Non-recirculating air curtains bring air into the fan housing through its intake and emits the air through its discharge nozzle. They are widely used in non-public doorways, such as those in factories and warehouses where the traffic is mostly vehicular rather than pedestrian. Therefore, the air speeds can be increased to 6,000 ft./min. and the thickness of the jet can be reduced to several inches. In general, non-circulating air curtain units are more effective, have lower

maintenance costs, and are easier and less costly to install. Depending upon the size of the openings, they can be mounted horizontally or vertically.

Recently, it has been proposed that an air curtain be installed on the east highbay door of the Kennedy Space Center's (KSC's) Operations and Checkout (O&C) Building to prevent/minimize the influx of dust particles when the door is open for payload access. Due to the size of the door (40 by 80 ft.), a vertically mounted, two-sided, non-recirculating air curtain has been selected for this application.

A search of the open literature indicates that test or operation data for a vertically mounted, two-sided air curtain under variable ambient wind are not available. Therefore, KSC has initiated an air curtain test project at the east highbay door of the Launch Equipment Test Facility (LETF).

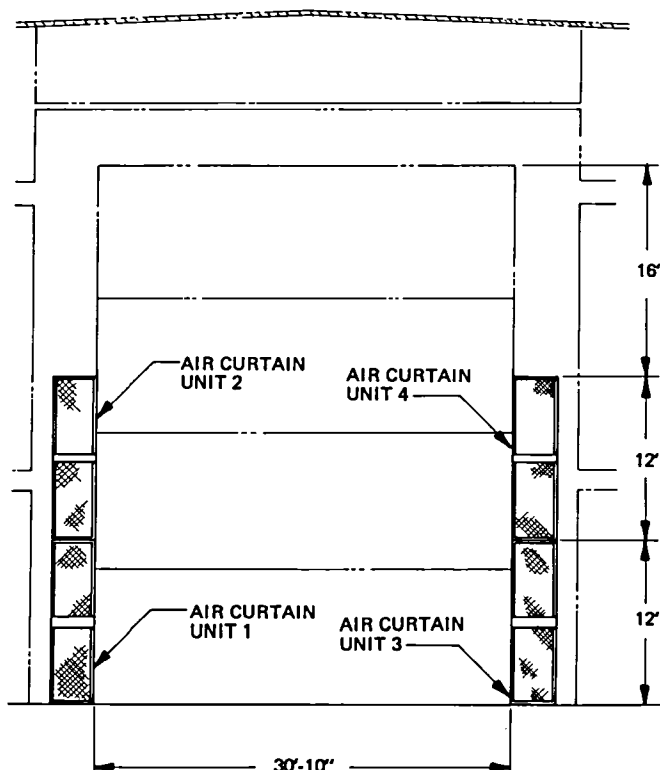
The objective of the test project is to study the flow characteristics of a vertically mounted air curtain and determine its effectiveness on preventing the influx of dust particles from entering a clean room.

The LETF east highbay door is 30 by 40 ft. As shown in the figure, "Air Curtains Vertically Mounted on Both Sides of the Left West Highbay Door Opening," two air curtain units are installed on each side of the door. Each unit has a 25-hp motor to drive four blowers at a speed of 983 rpm, an intake damper to control flowrate, and a 12-ft. long discharge nozzle to generate an air curtain. The nozzle has an adjustable angle of $\pm 20^\circ$ from its centerline, and an adjustable width of 6 to 8 in.

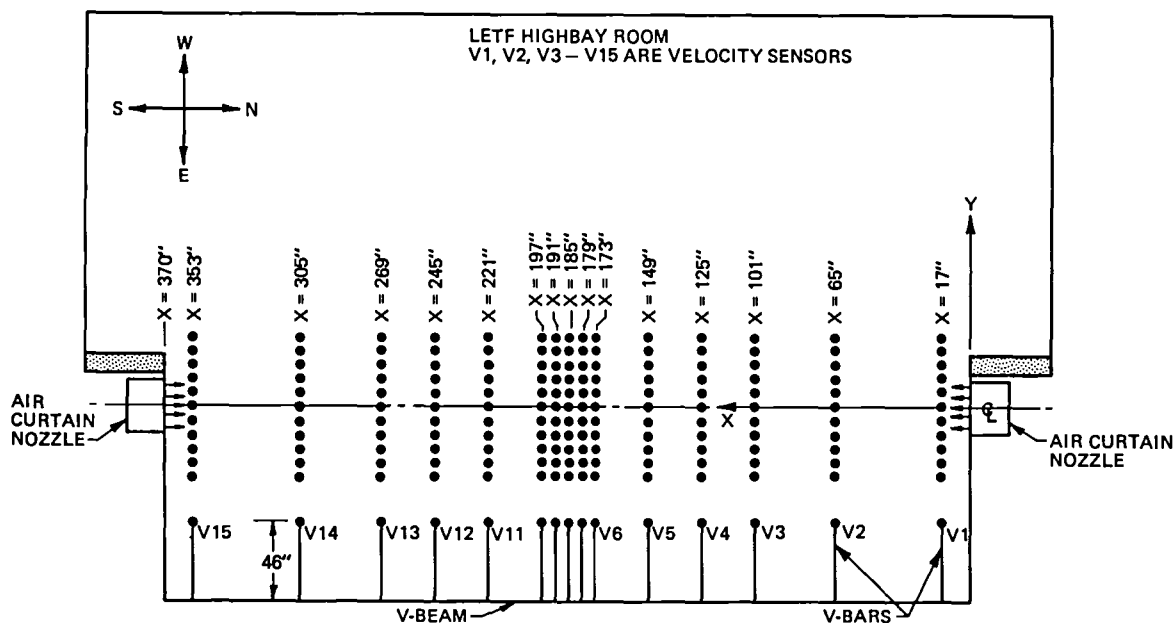
To achieve the test objective, an air filtration system and four particle counters have been installed in the highbay room to control and monitor the particle counts under various test conditions. Additionally, 15 velocity sensors are available for measuring the air velocities along the doorway. As shown in the figure, "The Velocity Beam and Sensors at Any Selected Elevation," the 15 velocity sensors are mounted at the ends of 15 V-bars, which are extended from a V-beam. By moving the V-beam in or out of the highbay room at any selected elevation, the velocity profile at each sensor location can be determined.

During each test, the ambient wind speed and direction are also recorded. The ambient wind speed and direction sensors are located above the roof of the highbay.

Several tests with various nozzle angles, widths, and discharge velocities have been conducted since August 7, 1985. A test report will be available soon.



Air Curtains Vertically Mounted on Both Sides of the Left West Highbay Door Opening



The Velocity Beam and Sensors at Any Selected Elevation

Simulation of Steady Liquid-Vapor Flow Under O-G Using Immiscible, Neutrally Buoyant Droplets in Water

Since boiling and condensation offer the advantage of high heat transfer rate, two-phase (liquid and vapor) flow systems have been recognized and proposed as the most effective and desirable thermal transport system for the Space Station. To design such a system, two-phase flow and heat transfer data in micro-gravity are essential.

Two-phase flow and heat transfer data in micro-gravity are also essential for an on-orbit handling of cryogenic propellants and the design of advanced space systems, such as Orbital Transfer Vehicles.

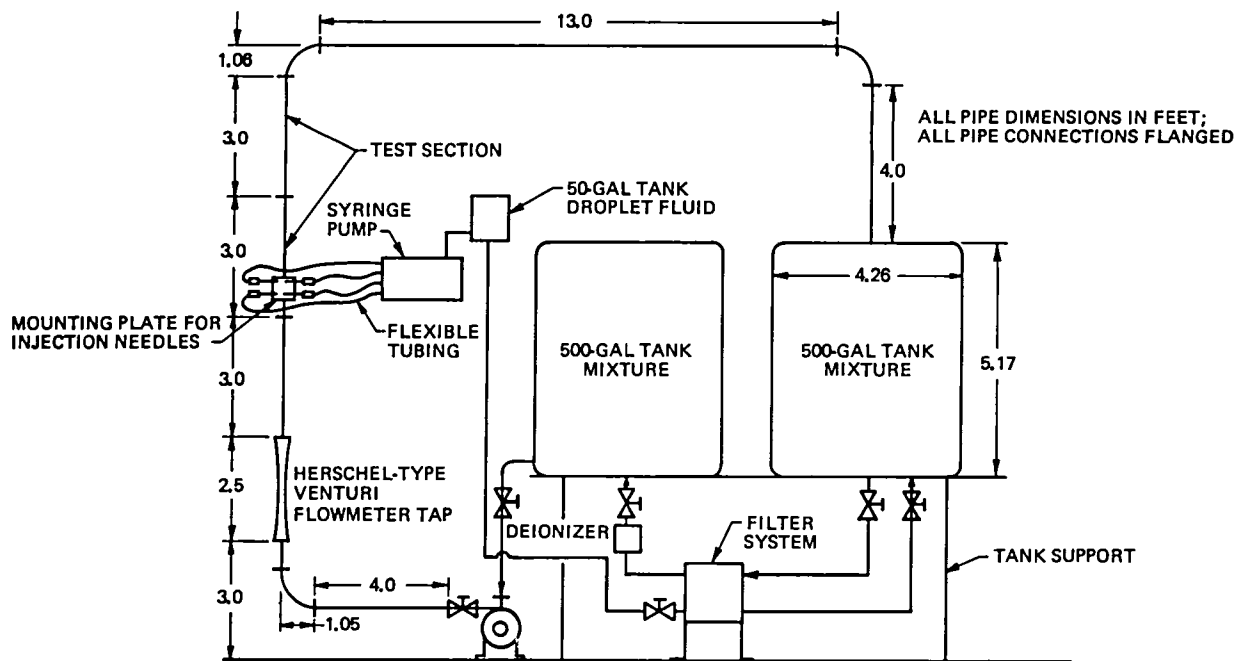
Recognizing the need for low-gravity two-phase flow and heat transfer data, KSC has awarded a contract to the University of Illinois to establish an earth-based test facility to simulate steady vapor-liquid flows under zero- and micro-gravity conditions. The simulation is to be accomplished by performing experiments using droplets of an immiscible liquid of neutral buoyancy in water. The two-phase systems to be simulated are liquid and vapor oxygen, liquid and

vapor hydrogen, liquid and vapor freon, and liquid and vapor ammonia.

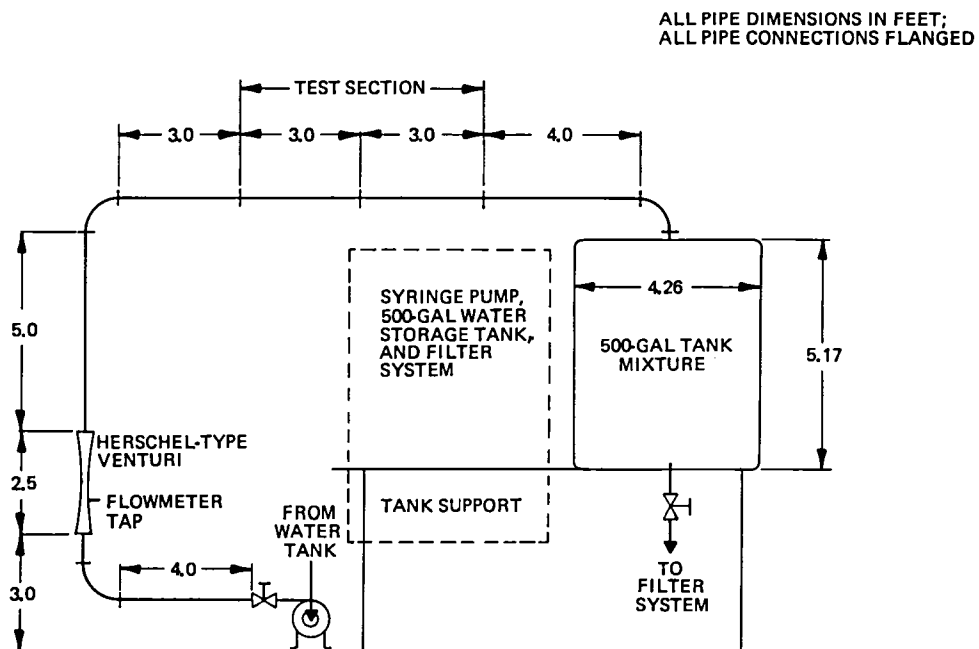
The basic objective of this research project is to map flow patterns and to provide pressure drop data for two-phase flow in conduit under zero- and micro-gravity environments. Once such information is available, the project shall examine non-isothermal systems involving vaporization and condensation to provide heat transfer data. The experimental apparatus can also study bubble dynamics in low-gravity environments.

The experimental apparatus for this project is shown in the figure, "Vertical Layout of Two-Phase Test Loop." Water is drawn from a 500-gallon storage tank and pumped into a transparent, square test section where the liquid droplets are introduced near the inlet. The test section can be positioned vertically or horizontally, as shown in the figure, "Horizontal Layout of Two-Phase Test Loop," or at an inclined angle. A Herschel-type venturi will be used to measure the water flow rate.

Some details of the test section are shown in the figure, "Experimental Test Section (Horizontal View)." The test section will be fabricated from Plexiglas, Perspex, or other transparent material; it must be chemically inert to the droplet liquids. The syringe needles for introducing the droplets are firmly held on mounting plates which fit into windows on the two opposite walls of the test section. Each plate will have two nee-



Vertical Layout of Two-Phase Test Loop

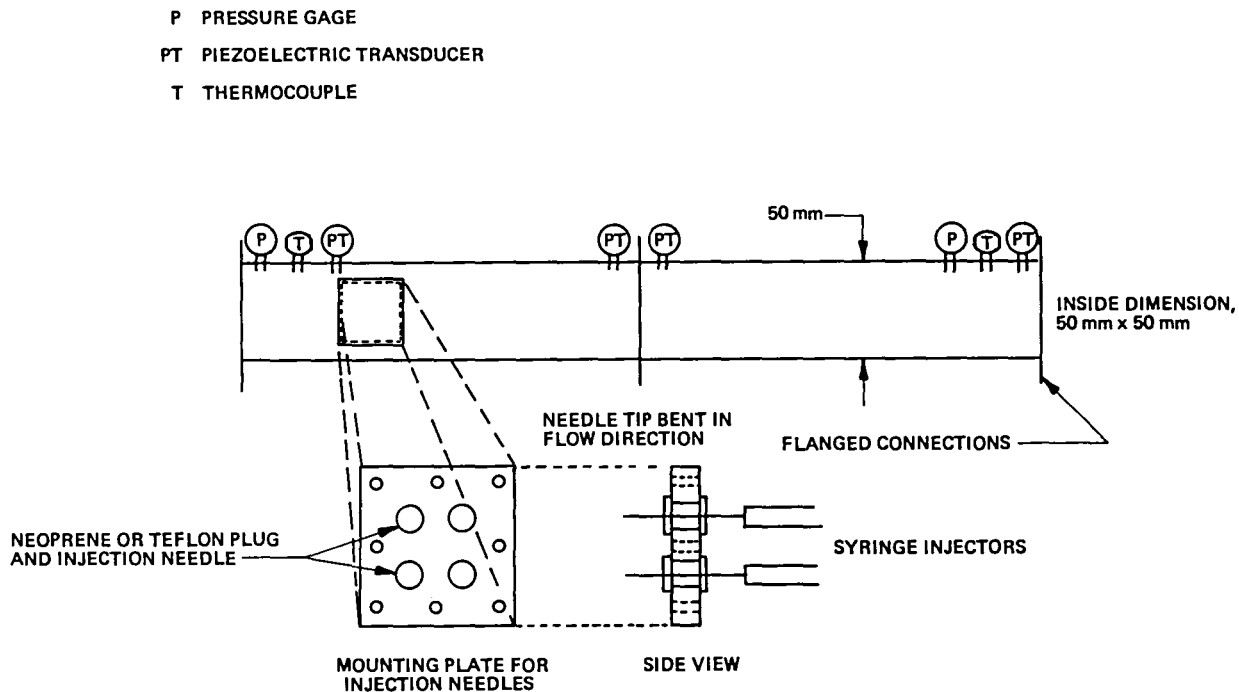


Horizontal Layout of Two-Phase Test Loop

dles with their tips bent in line with the main flow direction; they are configured to avoid coalescence or break-up of the droplets in the region where they are formed and detached. Piezoelectric pressure transducers will be used to determine not only the time-averaged pressure drop along the test section, but also the local, instantaneous pressure fluctuations. The latter is known to be characteristic of the two-phase flow regimes. The test section consists of two separate sections, each one meter long, connected by flanges. In future studies, an intermediate section with converging, diverging, or sudden expansion features will be added.

The two-phase fluid mixture emerging from the test section flows into a second 500-gallon storage tank. Both tanks are to be fabricated from polyethylene. Because of the high cost of the syringe pump and the slow filtration process of the membrane filters, the experiments are to be conducted in a batch fashion. A test duration of approximately 2.5 hours is available for a pipe Reynolds number of 5,000 at the test section and a maximum droplet volume fraction of approximately 3.4 percent.

F. N. Lin
DD-MED-1 867-4156



Experimental Test Section (Horizontal View)

The Effect of Sense Line Length on Pressure Spike Measurements in Cryogenic Flow

The existing pressure transducers in the liquid oxygen main propulsion system at the Kennedy Space Center (KSC) are connected to the pipe with long sense lines — 30 ft. for the Orbiter inlet transducer, 37 ft. for the skid outlet

transducer, and 29 ft. for the skid inlet transducer. While the long sense line does not effect steady state pressure measurements, it does effect the accuracy of transient measurements, such as pressure spikes. Testing had been done previously with no conclusive description of the phenomenon; therefore, a continuation test was performed at KSC's prototype laboratory.

Instrumentation was mounted on 40 ft. of pipe in which a spike was generated by flowing liquid nitrogen from a tanker through the pipe and closing a butterfly valve. The test configuration instrumentation included a turbine flowmeter, two temperature transducers, and

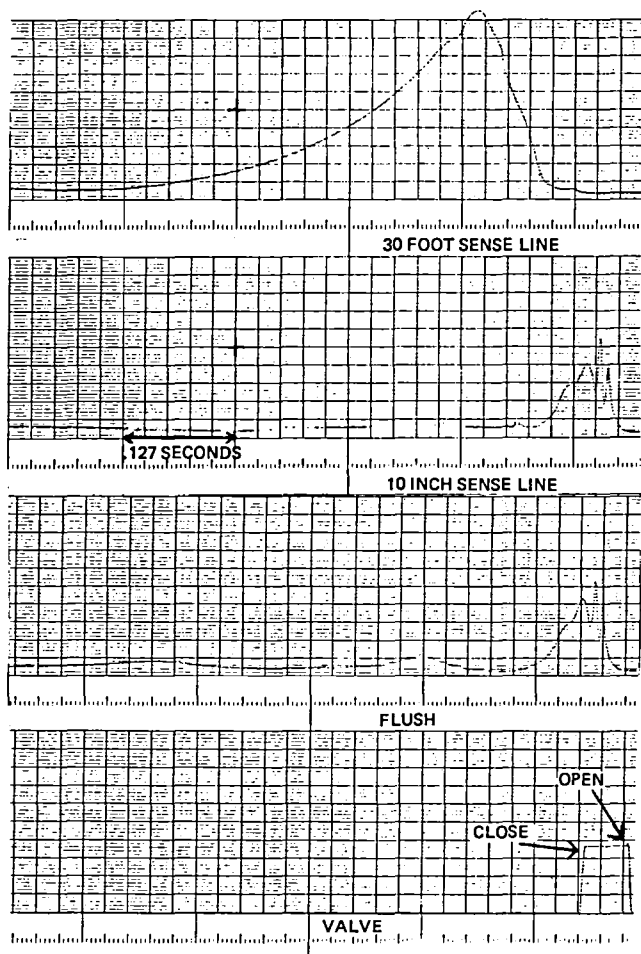
three pressure transducers. The three pressure transducers were connected to 30-ft., 10-in., and ½-in. sense lines. The ½-in. sense line was essentially flush to the pipe. The flush pressure transducer was used to determine the actual pressure spike that the pipe encounters, which then was compared to the 30-ft. and 10-in. sense line measurements. The sense lines all were mounted on the top of the pipe ¼ in. from each other and 1 ft. from the closing valve. The flowmeter allowed an approximation of the pressure spike energy. The spike energy was varied by changing the liquid nitrogen flowrate.

The test results indicate that the 10-in. sense line measures the same pressure spike form as the flush pressure transducer, and that the duration of the spikes are the same. When comparing the magnitudes of the pressure spikes, it appeared that the flush pressure transducer measured a slightly higher spike magnitude than the 10-in. sense line. This may be because the flush transducer must withstand cryogenic temperatures; therefore, the transducer itself has a

different design and range than the ambient pressure transducers. There was no time lag in measuring the pressure spike after the valve closed with the flush or 10-in. sense line measurements. The flush and 10-in. sense line transducers have three spikes within a spike as the valve closes. The phenomenon of three spikes occurring within a spike may be explained by the following: As the valve initially closes, the gas in the sense line is compressed as the liquid partially moves up the sense line. The pressure then decreases as the gas in the sense line condenses because of liquid nitrogen contact. This process repeats as the pressure in the pipe increases while the valve closes, and the final spike occurs exactly when the valve closes.

The 30-ft. sense line pressure spike measurement differed from the measurement of the flush and 10-in. sense line transducers. The 30-ft. sense line generally recorded a longer duration and magnitude of pressure spike. The shape of the spike was rounded and had a time lag from when the valve closed. The 30-ft. sense line acted similar to a surge tank, causing a delay in recording the pressure surge, as well as smoothing the data. A comparison of the three pressure measurements are shown. Each pressure spike shown has the same energy.

The flush pressure transducer measures the pressure that the pipe encounters; therefore, the 10-in. sense line allows the pressure transducer to measure the actual pressure spike. The 30-ft. sense line distorts the actual pressure spike so that an erroneous measurement is recorded. Pressure plots for the various sense lines may be compared in the figure below.



Comparison of a Pressure Spike Measurement Varying Sense Line Length

K. Buehler, 867-3332

DD-MED-43

Magnetic Reliquefaction of Hydrogen

Under a Kennedy Space Center (KSC) contract, Los Alamos National Laboratories has been developing the technology of refrigeration of hydrogen from -320 degrees Fahrenheit ($^{\circ}\text{F}$) to -423°F using the addition and removal of a magnetic field. Calculations have been made which show that refrigeration with magnetic fields can be made to be twice as efficient as refrigeration with conventional compressors and expanders (36 percent). This work is being performed to develop a lightweight, highly efficient refrigerator to be placed on top of the launch pad liquid hydrogen storage vessels to capture liquid hydrogen boiloff. The technology developed will

also have possible application in industry, space station, and moon and Mars launch bases.

Supercritical helium is being used as the cooling medium. The helium will flow through a heat exchanger made of a gadolinium compound, which is moved through the magnetic field to increase its temperature. The heat transferred to the helium will be removed by liquid nitrogen through a heat exchanger. Then the gadolinium material will be removed from the magnetic field, which will cause cooling. Heat will be removed from the helium by the cold gadolinium material, bringing it below liquid hydrogen temperature. The helium will increase in temperature as it liquifies the hydrogen. The cycle is then repeated.

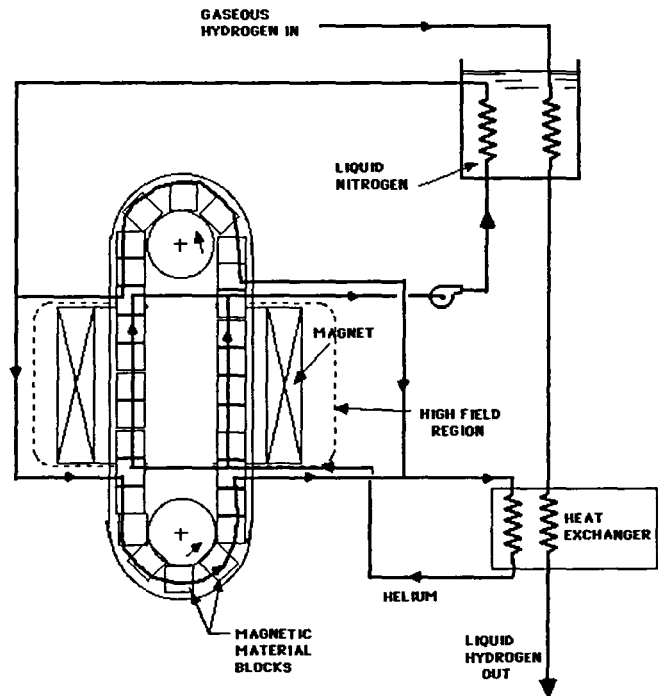
One of the key problems in the development is determining the best method of moving the helium and gadolinium material in and out of the magnetic field with the required helium flow and heat exchange to provide the high efficiency refrigeration desired. Los Alamos analyzed linear displacement and rotational devices. The configuration presently being analyzed is a combination of the two in a chainsaw configuration shown in the figure, "Schematic of the Magnetic Refrigerator Chainsaw Concept." This configuration enables the helium to make a dual pass through the high and low magnetic field regions, allowing the magnetic material blocks containing the magnetic gadolinium material to have sufficient time in the magnetic field for heat transfer.

Some basic problems still being worked are: the helium seals between the chainsaw configuration covering and the heat exchanger connections, the fabrication of the gadolinium material

for optimum heat exchange and avoidance of extreme thermal expansion stresses in the gadolinium, and the development of a high efficiency supercritical helium pump.

F. S. Howard, 867-3202

DD-MED-4



Schematic of the Magnetic Refrigerator Chainsaw Concept

SOFTWARE DEVELOPMENT

Rapid Prototyping Supports Space Station Operations Language Requirements and Concept Development

Kennedy Space Center (KSC), as a member of a Tri-Center team, is in the process of formulating requirements and concept specifications for a user interface language (UIL) to be implemented by the Space Station (SS) Program. The UIL will support user interface to SS systems, both on the ground as well as on orbit. KSC's role is the definition of requirements and a conceptual design for that part of the UIL which supports the Integration and Test (I&T) environment. The Space Station Operations Language (SSOL) System, a subset of the UIL, will provide support for members of the I&T community which includes: scientists, engineers, manufacturers of SS systems and payloads, systems integrators and SS crews. It will be used in the development and execution of integration and test procedures, starting with the initial development of components and systems through the ground integration process to I&T on board the SS.

In the process of defining requirements, it was determined that a method of interfacing with the user community to collect, validate, and verify requirements and concepts was mandatory. KSC's approach to develop valid requirements utilizes an interactive, rapid prototyping methodology to support the traditional requirements analysis, which is based on user interviews, revision and documentation review and revising. The figure, "KSC Focus on Needs of I&T Community" depicts the interaction between the traditional approach and the use of rapid prototyping.

Prototyping is a method of developing software products whereby the user is allowed to view and actually try out individual components of a system during its development phase. This method allows the user to visualize future operating procedures and to make modifications early in the development effort.

The standard life-cycle approach rarely provides the user with hands-on experience of the system until it is delivered as a final product. Frequently, what appears adequate on paper becomes impractical when put into operation. What inevitably follows is a stream of requirements changes to modify the software product to

reflect revised user's needs.

Rapid prototyping provides an alternative approach to the generation and validation of written requirements specifications, and is a method of ensuring that a software product will be responsive to the user's needs.

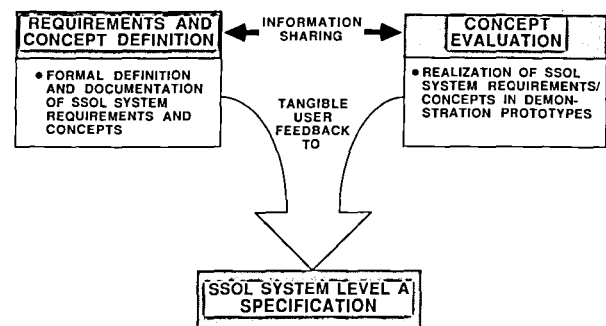
In brief, rapid prototyping is a structured method of breaking down a system into integral components which can be exercised independently by the user as development proceeds from requirements definition through design and implementation. As software components are developed one by one, selected components are implemented as prototypes for user trial interactions. Revision is accomplished by incorporating the user's changes. Also, any second-order impacts, such as revisions to the user's mode of operation, can be evaluated and responded to during this process.

In order to support the process of prototyping user SSOL requirements, an interactive demonstration facility was developed and equipped with terminals, graphic display units, large screen projectors, sound, and a VAX 780 computer. This capability provides an environment for direct interaction between users and developers as shown in the figure, "KSC Focus on Needs of I&T Community."

Software concepts are prototyped to portray various features of the SSOL System. A number of the prototypes demonstrate alternative approaches for the same functions. For example, a concept is prototyped using text on a standard display terminal as one method of operation. Also, the concept is prototyped using icons on a

KSC APPROACH

- PROVIDES CONCRETE EVALUATION, VALIDATION, AND REFINEMENT OF SSOL SYSTEM REQUIREMENTS/CONCEPTS



KSC Focus on Need of I&T Community

graphic terminal to accomplish the same operation. These two approaches then can be compared and the more appropriate or preferred method implemented.

As requirements evolve, they are incorporated into the prototype for user interaction. Users are encouraged to comment on the desirability of an approach, and suggest improvements that could be made to the demonstrated prototype. The user comments are evaluated, and where appropriate, are included in the next version of the prototype.

The initial prototype took the form of a demonstration. It will be followed by an interactive working prototype that will provide the users of the SSOL System with hands-on experience.

A number of initial concepts have been demonstrated to the I&T user community in the prototype environment. Concept and capabilities demonstrated include: direct development of

procedures from graphic representation of the test item; use of global statements to consolidate a number of individual statements into one statement (thus reducing run time while speeding up test processing); an interface with embedded processors; a language-support environment to interface with the host, target, and test systems; on-line configuration management; and graphic workbench support.

To summarize, the use of prototype provides a more realistic validation of user requirements than reviewing specifications and manuals. Prototypes make it possible to generate several alternative systems for comparison, and provide quick-response solutions for user difficulties.

L. Wilhelm, 867-7582

DL-DED-21



SSOL Demonstration Area, EDL Room 104



SSOL Demonstration Area, EDL Room 104

LPS Software Development Network — A New Approach to An Old Problem

Tasked with supporting an increasing launch rate while reducing overall operating costs, the Shuttle Processing Contract (SPC) finds itself facing a sizable dilemma in the area of Launch Processing System (LPS) Engineering and Software Production. With no projected decrease in change activity expected, the need to address software productivity through innovative tools becomes the highest priority. Compounding the deficiencies in the existing system is the reallocation of computer resources. Equipment once dedicated to software development is now required for Shuttle operational testing and launch activities. A synopsis of the potential magnitude of this problem is depicted in the figure, "Problem Summary."

Further, the problem is multifaceted and steeped in a large number of manpower-intensive tasks. Some of the key problems to be overcome are outlined below.

1. The GOAL application program development is hampered in many ways. Due to the batch-type environment existing on the Central Data Subsystem (CDS) and to a lesser degree, the current level of loading on CDS, the turnaround time required to correct errors found at compilation time varies between a half and a full workday. It requires approximately three to five days to enter a program initially into Firing Room Debug, and one day to turn around errors not discovered until debugging. Since GOAL programs cannot be tested on CDS,

many problems are discovered in debugging. It requires approximately one week to enter verification and one day to turn around a problem found there. GOAL application program maintenance involves 9,586k lines of user code at over 100 changes per month.

2. LPS Checkout, Control & Monitor Subsystem (CCMS) firing room system software development is facing obstacles that are even more severe. Every principal activity required to maintain firing room system software (that is, code editing, code assembly, link edit, debug, integration, and validation) requires exclusive use of either the Software Development Laboratory (SDL) or a firing room set. These resources not only are inadequate for the bulk of this task, but also are overextended. LPS/CCMS system software program maintenance involves 2.5 million lines of code at 10 Engineering Support Requests (ESR's) and 50 Software Problem Reports (SPR's) per month.
 3. LPS/CCMS documentation is another problem area. No available system is able to produce the integrated word processing and graphics required. User guide documentation is maintained on off-line word processors, and the graphics for these documents are manually drawn and inserted later by hand. Design documentation for the same subject is maintained on the SDL, and updates must be scheduled as dedicated facility block time. LPS/CCMS documentation maintenance involves 44k pages at 800 page changes per month.
- Even though a single programmer is responsible for incorporating both a change in software and documentation, the use of multiple facilities forces the involvement of additional support personnel and longer development times.
4. Finally, configuration management has never been integrated across LPS products since it was accomplished by different incumbent companies. This has led to the establishment of many manual steps, and the involvement of numerous support personnel.

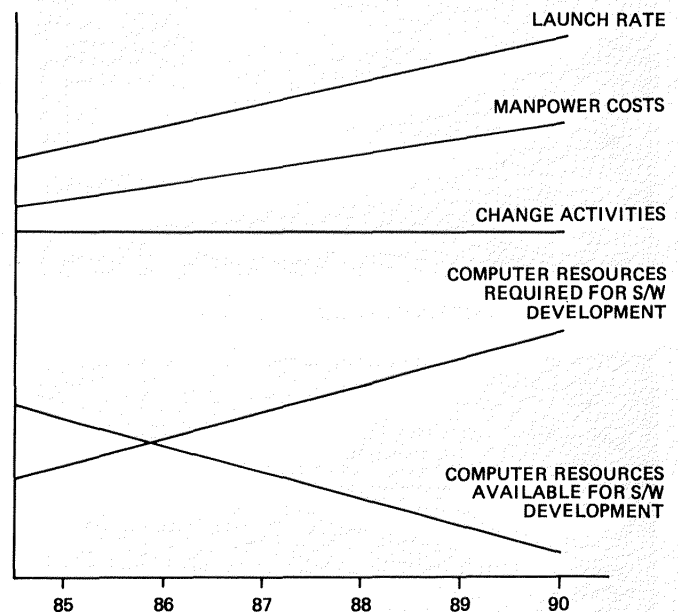
While each of these problems could be individually and systematically attacked and to varying degrees solved, this approach would be expensive. The real problem underneath is that the basic means, or rather, the basic technology used to accomplish these tasks, is out of step with the job to be done, having been displayed by rapidly marching technology.

In an attempt to resolve these problems, a prototype local area network (LAN) was procured to support development of software for the Shuttle Centaur modifications. This network provided the basis for the LPS Software Development Network (LSDN). Using state-of-the-art resources

available on the network, the network was utilized in a trial investigation which demonstrated how aspects of each of the major types of work done by LPS Engineering and Software Production would evolve under the LSDN concept. This effort also established a basis for estimating factors of the proposed system, such as: overall cost, basic requirements for procurement, magnitude of the software development task to be undertaken or contracted out, as well as the value and offsetting benefits of the production system.

Once the LSDN concept system was completed, demonstrations were given to SPC and NASA management actually showing how LSDN could be used to revolutionize work in each of the areas mentioned. One existing aspect of the LSDN is its rapid payback in projected manpower savings of two years. The concept was widely accepted and a go-ahead was given by SPC and NASA management to procure and develop a production LSDN system.

LSDN consists of workstations tied into LAN linking both Kennedy Space Center (KSC) and Vandenberg Launch and Landing Site (VLS) [(see the figure, "Conceptual Diagram of the Production LSDN system")]. LSDN has the following major characteristics:



Problem Summary

1. Workstations are 32-bit class computers.
2. Workstations support:
 - a. UNIX
 - b. Fortran '77
 - c. C
 - d. Ada
 - e. Common Lisp

- f. Codasyl compliant data bases
- g. SQL-style relational data bases

3. LAN supports:

- a. At least expansion to 400 workstations
- b. Access to CDS, Kennedy Data Management System (KDMS) and NASA's office automation system at KSC
- c. Satellite tie between KSC and VLS

A study was made of GOAL application software development currently carried out by LPS Engineering and Software Production. The methods presently used are similar to those used by previous SPC contractors. The purpose of the study was to determine:

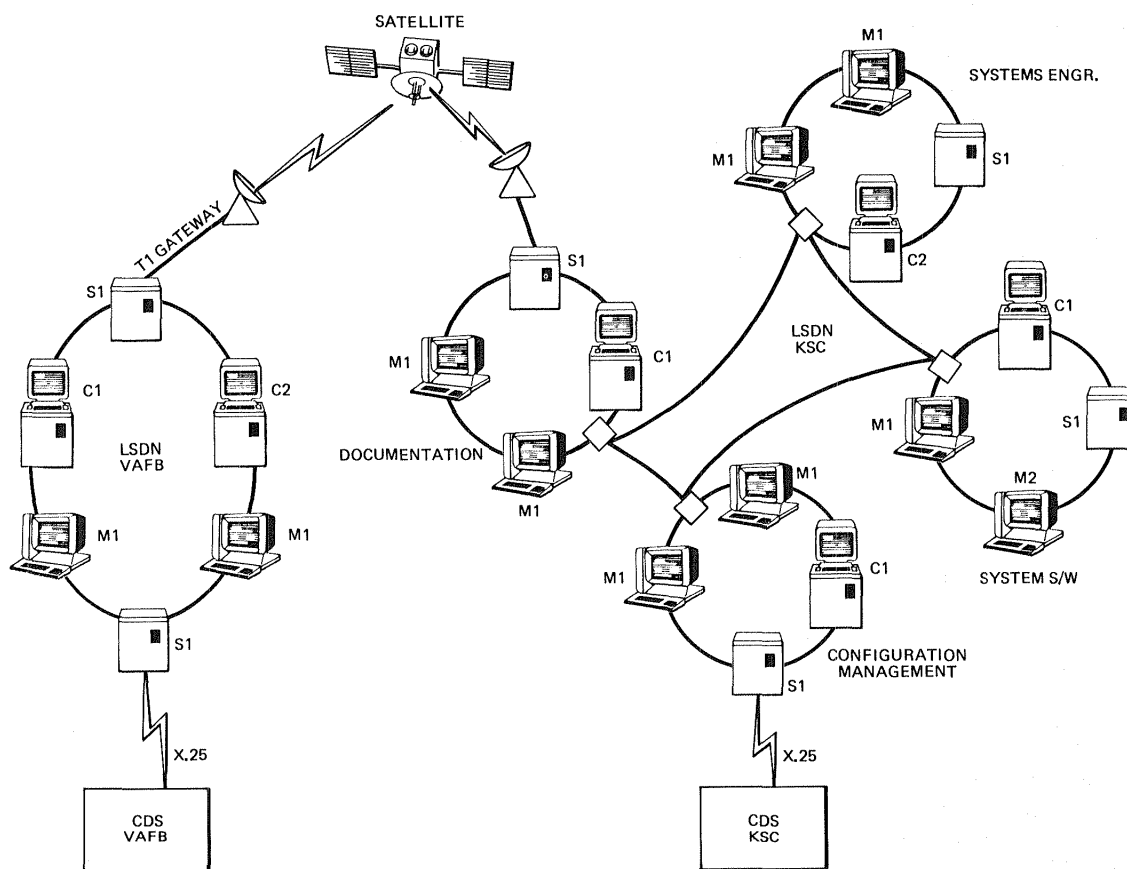
1. How much turnaround time and manpower is required to implement typical GOAL changes.

2. How this time and manpower is divided into the various code development activities.
3. What improvements are feasible with LSDN and other technologies.
4. What the best cost-effective changes are that can be made to optimize GOAL application development.

The study revealed that all of the GOAL application software development, except for verification, was practiced to be done on LSDN workstations right in the office environment. The resulting savings would reduce change turnaround time by over 50 percent and manpower by 30 percent. It will also save valuable firing room testing time and CDS resources.

J. Medlock, 867-6213

SE-GDS-1



Conceptual Diagram of the Production LSDN System

Hydrazine Adsorber and Neutralizer

A feasibility study was performed by Auburn University to develop a material that could be applied to an unwanted liquid hydrazine spill to adsorb and safely neutralize the fluid; then subsequently dispose of it without special protective measures. Contacting schemes and neutralization reagents were investigated and ranked for further development. The most promising concept appeared to be metal oxides selectively deposited on zeolite or pillard clay surfaces.

Thus, a laboratory research and development effort is presently being conducted with Auburn to characterize and tailor surface reaction and adsorption kinetics of various materials. First row transition metal oxides, as well as zinc and tin oxides and selected sulfates have been characterized by X-ray Photoelectron Spectroscopy and subjected to identical hydrazine exposure for relative reducibility.

Since cupric oxide displayed the highest reactivity, reduction characterization, and kinetic, controlled atmospheric, and angle-resolved studies were performed. It was found that lattice oxygen is preferentially removed by hydrazine compared to surface hydroxyl or strongly chemisorbed oxygen, and the reduction is a first-order reaction dependent upon the amount of CuO available in an excess amount of hydrazine. It was also verified that hydrazine is molecularly adsorbed on copper metal, and varied pressure does not introduce catalytic reactions. The theory of a metallic copper layer being formed upon a cupric oxide substrate was also confirmed. Adsorption isotherms have been measured using microgravimetrics with pillared bentonites and silica alumina supports. It was concluded that hydrazine is only condensed in the interlayer and interpillar structures of the bentonites, whereas both physical and chemical adsorption occurs with silica alumina materials.

This new information may enable one to design an optimized substrate and metal oxide combination for controlled adsorption and neutralization of hydrazine under various concentrations and pressure environments. Further activities are planned for laboratory research, prototype development, and testing.

R. A. Gerron, 867-4493

SF-ENG

Study of Coatings that Require Minimal Surface Preparation for Potential Application on LC-39 Structures

With the evolution of the Shuttle program, the coating systems used to protect the structures at Launch Complex (LC)-39 have experienced localized failures. These coatings were developed during the Apollo program to protect the structures from Kennedy Space Center's (KSC's) marine environment and the byproducts of the rocket exhausts from the launch vehicles of that era.

The Shuttle launches have changed the LC-39 environment. The exhaust products from the Shuttle Solid Rocket Boosters (SRB's) contain hydrochloric acid, aluminum particulate, and other elements. The heat and exhaust products have, in some cases, destroyed the protective coatings on the launch pad structures and caused their corrosion.

Ongoing work is being performed to evaluate ablative materials, conductive organic polymer coatings, plasma spray coatings, and other coating systems. In application, many of these approaches will have drawbacks. The material may be prohibitively expensive, or it may require extensive surface preparation, such as sandblasting, which can impact the pad operations between launches or contaminate critical ground-support equipment (GSE) and flight hardware.

It would be desirable to have a simple, inexpensive repair coating system which requires minimal surface preparation for the LC-39 structures.

In conducting the study, coatings will be applied to the structures over corroded areas which have only been prepared by wire brush. This will evaluate the coatings' ability to withstand the pad environment.

P. J. Welch, 867-4614

DE-MAO-2

Conductive Organic Polymers as Corrosion Control Coatings

The objective of this study is to develop coatings from conductive organic polymers that will provide galvanic protection similar to the inorganic zinc-rich coatings currently being used at Kennedy Space Center (KSC). These organic coatings should be formulated to provide easy application, repair, and long-term resistance to the KSC launch environment.

Several conductive organic polymers have recently been developed that are air- and light-stable. These polymers were originally developed for battery and semi-conductor industrial applications. The first step is to develop formulations of these polymers that permit their use as coatings. The second step is to incorporate a sacrificial material, such as zinc, into the coatings. The third step is the evaluation of these polymers as corrosion-preventive coatings for iron and steel substrates. Three basic polymer systems are of interest: polyaniline, being developed by researchers at the University of Pennsylvania, and polpyronne and polyphenylquinoxaline, being developed at Los Alamos National Laboratory.

These studies will focus on formulation, application, and evaluation. Final evaluation will be performed by exposure testing at the KSC beach corrosion site.

C. J. Bryan, 867-4614

DE-MAO-2

Evaluation of Sealants for Dissimilar Metal Corrosion Prevention

It is well known that two dissimilar metals in contact in the presence of an electrolyte form a galvanic cell. The anodic metal will corrode, while the cathodic metal will enjoy a degree of protection. A commonplace example of such dissimilar metal application is the use of stainless steel screws to join aluminum alloy parts of fluid system components, such as valves. Corrosion of the aluminum alloy can weaken or destroy the threads, relaxing the clamping force of the screws. The corrosion products are more voluminous than the metal from which they are formed, and given sufficient grip length and thread engagement, the corrosion products can exert enough pressure between the screw and the wall of the hole to seize the screw so that

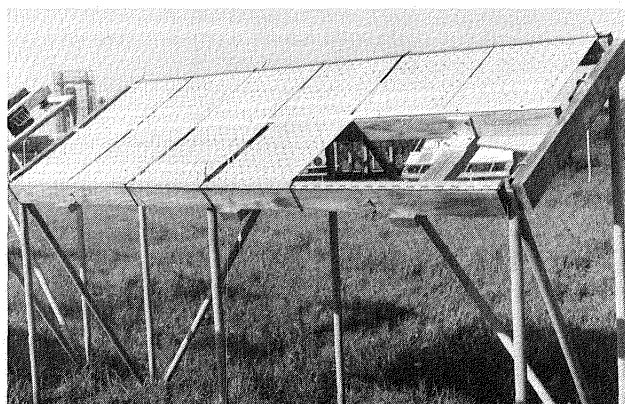
efforts to remove it only lead to wringing off the head. Prevention of this kind of corrosion is needed in the interest of performance and the reduction of cost and maintenance.

A study has been initiated to determine the effectiveness of a number of commercial sealants or corrosion inhibitors in controlling the corrosion of threads in aluminum alloy, when used with stainless steel screws.

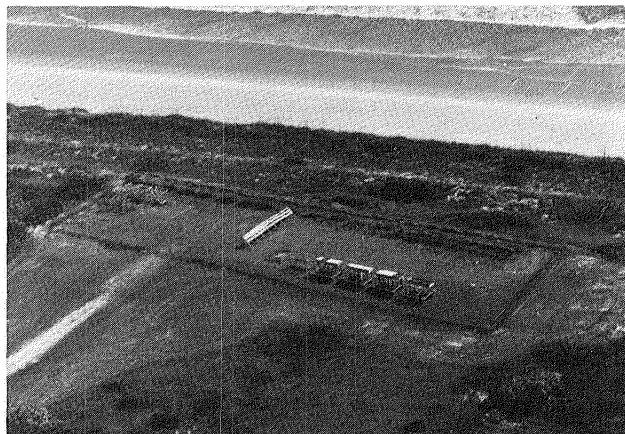
Aluminum nuts and stainless steel screws were assembled with a uniform torque on aluminum panels, using the various sealants. All of the sealants were represented on each panel. The panels are exposed at the Kennedy Space Center (KSC) Beach Corrosion Test Site. A schedule has been established whereby exposed panels are returned to the laboratory periodically for examination. The break-loose torque is determined, and the nuts and bolts and panels are examined for evidence of corrosion.

C. V. Moyers, 867-4614

DE-MAO-2



Refractory Test Panels and Corrosion Test Panels



Aerial Beach Corrosion Site

Accelerated Corrosion Test Method for Zinc-Rich Coatings

Some zinc-rich coatings for protecting iron structures are durable in coastal environments, with the better coatings having life expectancies of over 15 years. However, the poorer coatings can become ineffective in as little as six months.

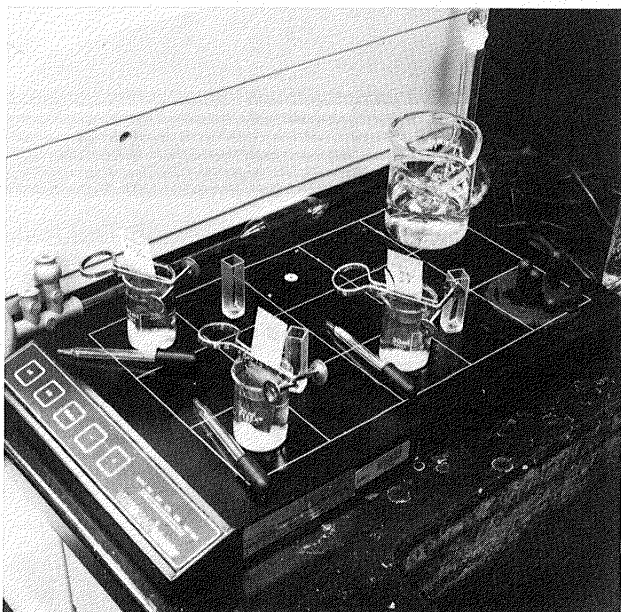
Currently, laboratory screening tests are not available for predicting the life expectancy of a coating; so, exposure to marine environments for up to five years is necessary to characterize the quality of a coating. Obviously, the waiting period is undesirable.

The laboratory screening test now being investigated is based on the rate of replacement of Zn in the paint with Cu from a copper sulfate solution. The rate of the reaction should be related to the availability of zinc metal, which probably determines the effectiveness of the coating (assuming these coatings are an extension of the galvanizing protection process).

Initial tests show a good correlation between the laboratory experiments and beachside corrosion data. Further comparisons with beachside corrosion for different paint samples are planned over the next two years.

C. W. Hoppesch, 867-7051

DE-MAO



Samples Under Test

Applicability of Acoustic Emission Monitoring to Pressure Vessel Testing

An acoustic emission (AE) event is defined as a localized material change giving rise to an acoustic wave. This can result from crack propagation or other phenomena which causes elastic or plastic deformation of the material. Specialized instrumentation is used to detect and locate the origin of the acoustic waves.

AE is becoming an accepted nondestructive test method for tanks and vessels in the petrochemical industry. At Kennedy Space Center (KSC) as at other NASA centers, work is being performed to apply AE testing to high-pressure vessels. To date, work has been performed to evaluate the AE event source location capability of commercially available AE testing equipment.

The evaluation was performed by mounting AE sensors on a low-pressure vessel and simulating AE events by breaking pencil leads on the vessel surface.

P. J. Welch, 867-4614

DE-MAO-2



Evaluation of AE Testing Equipment by NASA Personnel

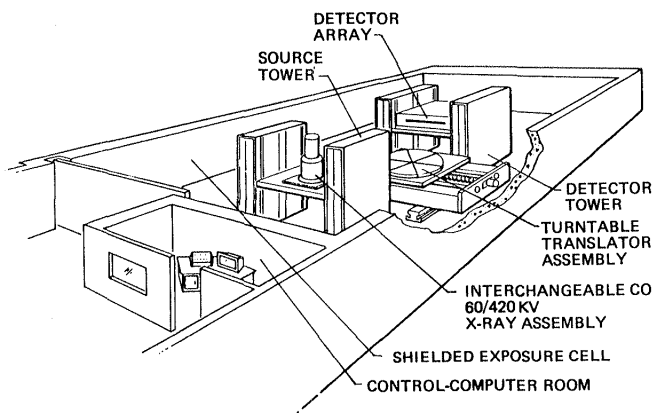
Computer Tomography

Kennedy Space Center (KSC) has initiated a project to develop and implement an industrial computer tomography capability. One of the key objectives of this effort is analytical versatility. To date, the majority of computer tomography systems, both medical and industrial, are designed

for a fairly narrow band of applications. The typical nondestructive evaluation (NDE) requirement at KSC is highly varied, ranging from component specification verification to failure analyses support on items of varying size and material composition. Therefore, a highly versatile system would provide the greatest benefits to NASA, and its contractors and customers. The system is designed to scan objects up to 6 ft. in height, 5 ft. in diameter, and weighing up to 2,000 lb. The interchangeable radiation sources consist of a variable 420 KV constant potential x-ray unit and a 1.2 MEV, 20 curie, Cobalt 60 source, providing penetration capabilities from very thin, low-density materials up to a steel-equivalent thickness of approximately 8 in. The system will have variable source and detector collimators, a 127-element detection system, and a data processing unit capable of processing/enhancing the radiographic images. Processed data will be presented in video or hard copy format.

This capability is being developed for NASA by EG&G (KSE NDE support contractor) and is scheduled to be operational by January 1986. Protracted testing is expected to consist of a combination of routine analyses and analytical development. This capability and data generated as a result of this effort should be of benefit to NASA, its contractors, customers, and other users of industrial computer tomography, who have wide potential applications.

J. W. Larson, 867-3423 or 867-2997
SI-PEI-3A



*Kennedy Space Center
Computer Tomography Facility*

Material Compatibility

Objective: Determine which type (or types) of commercially available tubing permits optimum sampling of hydrazine-contaminated air over the extremes of temperature and humidity encountered in field conditions.

Background: It is necessary to monitor areas in which hydrazines are stored and/or handled in order to protect personnel from the toxic properties of these compounds. For several reasons, it is desirable to monitor a number of storage/handling areas with one fixed analyzer sampling through a network of tubing, whose sections may be 200 ft. long or more. Since hydrazines are highly reactive compounds and have a tendency to collect and decompose on surfaces, it is necessary to determine which tubing most suitably transports airborne hydrazine vapors, especially as technological advances permit detection of lower levels and established threshold limit value (TLV) levels continue to drop.

Approach: Subject tubings were selected on the basis of known or suspected hydrazines' compatibility, cost, flexibility, and heat resistance. Each subject tubing was exposed to the TLV level [200 parts per billion (ppb)] of monomethylhydrazine (MMH) in otherwise clean air with controlled temperature and humidity, then pushed through at a flow rate of five liters per minute. The outlet end of the tubing was monitored for MMH concentration, using a chemiluminescence-based breadboard instrument developed by Thermo Electron Corp. (now Thermedics). A response curve of MMH concentration versus time, and the times required to reach 50, 75, 90, and 100 percent of the original MMH concentration (concentration measured without tubing) was measured for each subject tube. Tubings up to 75 ft. long were tested. Fluorocarbon tubings showed the best performance, although polyethylene tubes were adequate for some applications. None of the other tubings tested was acceptable. Further testing is underway.

J. C. Travis and W. Helms, 867-4438
DL-NED-32

ROBOTICS

Robotics Applications Development Laboratory (RADL)

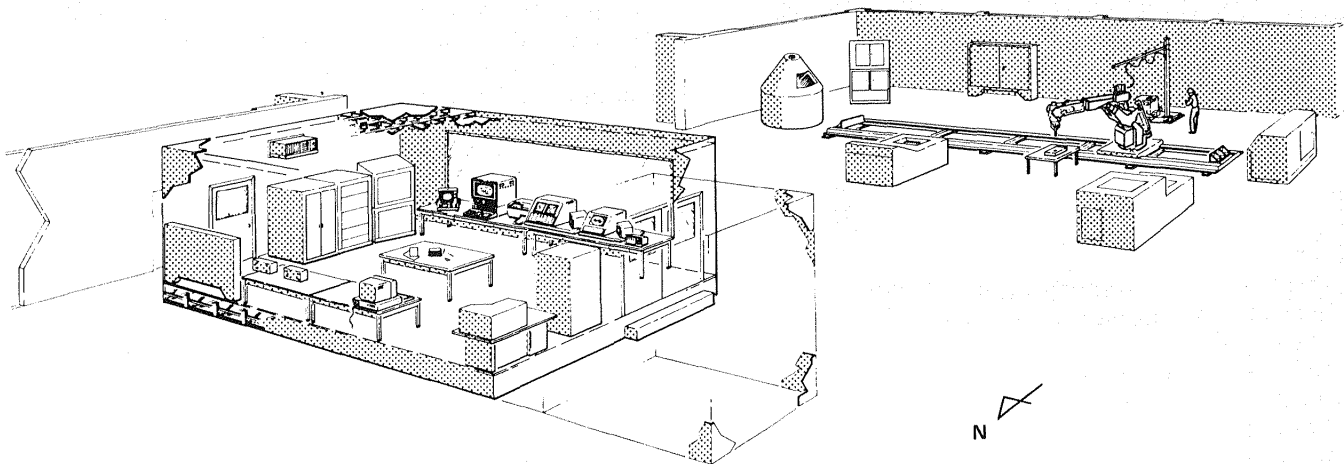
Background: Robotics technology is a rapidly advancing field which is moving from applications on repetitive manufacturing processes toward applications of more variable and complex tasks. Current directions of NASA design for the Space Station and other future spacecraft are moving toward the use of robotics for operational, maintenance, and repair while the systems are on orbit. These spacecraft systems will eventually require processing through Kennedy Space Center (KSC) for launch, refurbishment, and perhaps other rescue operations.

In the future, KSC will be called on to design processing facilities for new generation launch vehicles, such as the Second Generation Shuttle, Heavy Lift Launch Vehicle, and others. The design of such processing facilities should take advantage of state-of-the-art robotics technology to provide cost-effective vehicle processing.

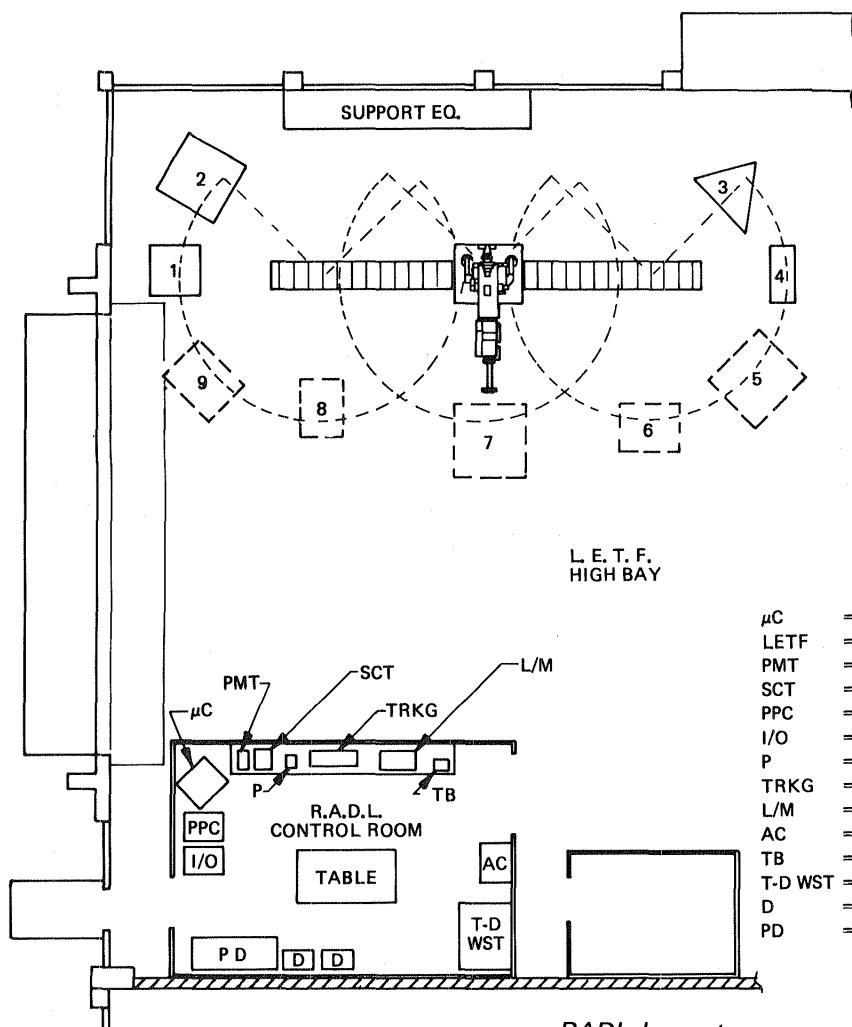
In addition to these future needs for robotics technology expertise, it is intuitively obvious that robotics technology could also have near-term applications to some of the existing hazardous and repetitive Shuttle and payload processing activities at KSC.

Therefore, KSC is developing a Robotics Applications Development Laboratory (RADL) in which robotics hardware, actuators, end-effectors, algorithms, software, sensors, and control systems will undergo conceptualization, development, evaluation, and checkout, using a large scale test article. The initial thrust of the RADL will be to develop the systems and techniques required for automated loading and unloading of hypergolics for space vehicles and payloads during prelaunch ground operations. Future tasks to be undertaken by the RADL will be to extend these automated techniques for other fluids (such as cryogenic), as well as electrical power, fiber optic communication, and data system connection/disconnection techniques. These ground operational techniques and systems will have direct application to future ground-servicing systems for launch of advanced vehicles and payloads. The developed techniques may also be applicable to space operational systems, since the space hardware being serviced on the ground at KSC will be the same hardware that will be operated in space.

Purpose: The initial purpose of this project is to develop a RADL at KSC that would provide a facility for training engineers in the unique/many characteristics/disciplines involved in robotics technology. It would also provide a facility where robotics technology testing could take place to develop the feasibility of applying such technology to current Shuttle/payload processing activities.



Robotics Applications Development Laboratory (RADL)



RADL Layout

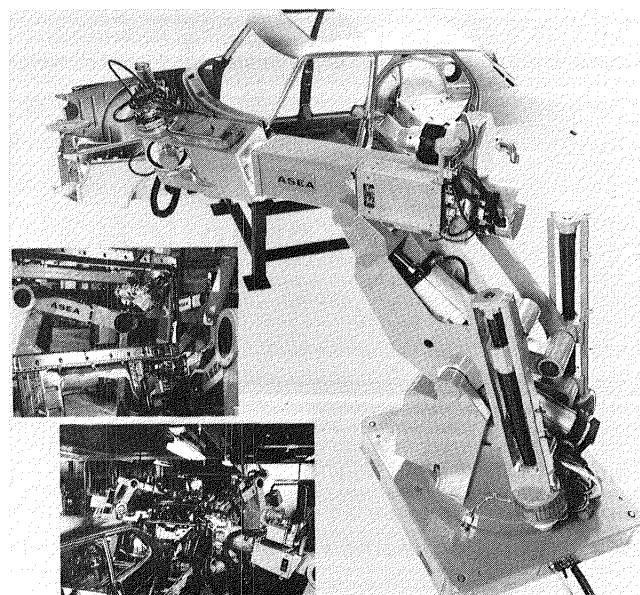
- μ C = MICROVAX II SUPERMICROCOMPUTER
- LETF = LAUNCH EQUIPMENT TEST FACILITY
- PMT = PROGRAMMING/MONITORING TERMINAL
- SCT = SMART COLOR TERMINAL
- PPC = PROGRAMMABLE PROCESS CONTROLLER
- I/O = INPUT/OUTPUT MODULES
- P = VIDEO HARDCOPY COLOR PRINTER
- TRKG = REAL-TIME TARGET TRACKING CONTROLLER
- L/M = VISION CONTROL FOR "LINES MANAGEMENT"
- AC = ROBOT ARM CONTROLLER
- TB = TEACH BOX (JOYSTICK CONTROLLER)
- T-D WST = THREE DIMENSIONAL WORKSTATION
- D = INSTRUMENTATION DISTRIBUTOR
- PD = PATCHING DISTRIBUTOR

The basic robotics laboratory would be equipped with an electrically driven, articulated robot (consisting of a 6-axis arm and interchangeable end-effectors), a computer and software system for applications development, and vision tracking system. As the expertise of the robotics engineers increases, and as application requirements dictate, the capabilities of the laboratory could be increased to include equipment for three-dimensional programming; higher order image processing; artificial intelligence; sonic, laser and other ranging systems; tactile systems; and mobility systems.

The ultimate purpose of this research will be to extend the lessons learned and techniques/systems developed to support existing ground systems, toward the development of similar systems for future ground servicing of advanced launch vehicles/payloads, and to evaluate the possibility of applying the new techniques to space operational systems.

V. L. Davis, 867-3402

DD-NED-22



ASEA IRB 90 Robot Arm Relative Size Comparison

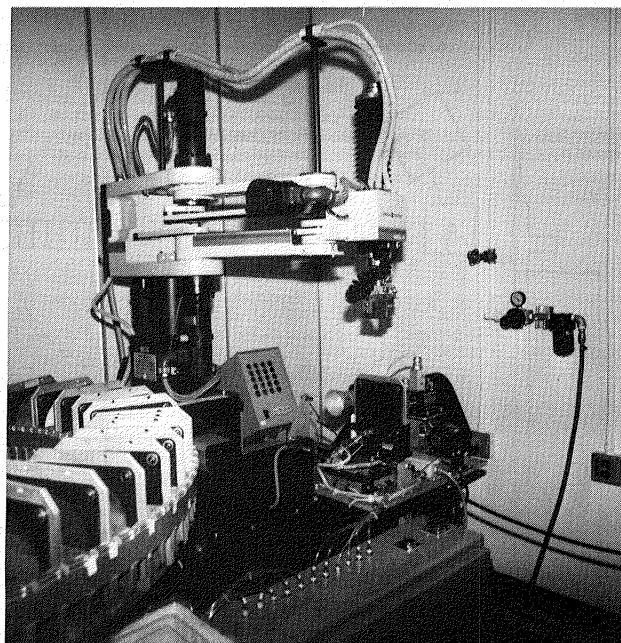
Electrostatic Robotic Test Cell

During 1964, NASA had a Delta third-stage solid propellant rocket sitting on a spin test at Kennedy Space Center (KSC). When the polyethylene dust cover was moved aside for maintenance, the plastic separated and an electrostatic charge of 37,000 volts was generated. The charge on the plastic caused another charge to develop on the outside of the rocket. Looking for the fastest route to a common ground, the current created a path directly through the solid propellant fuel. As a result, the laboratory was destroyed, three men were killed, and 11 other people hospitalized.

Since then, NASA has been concerned with the charges different plastics can generate. Due to the severity of the problem, the Material Testing Lab developed a procedure to test plastic samples for their charges generated, and discover how long the plastics will retain these charges.

This project was requested by the Material Testing Branch to improve the accuracy of the testing for the amount of static charge stored in materials. The materials tested are used in areas that are potentially explosive, such as the Shuttle Solid Rocket Boosters (SRB's), and the LH₂ and LO₂ storage areas at KSC. The Material Testing Branch also tests samples for other government agencies and industries on request, to verify their compliance with safety regulations.

The major problem has been that the testing has to be done manually and is time-consuming and inaccurate. This testing would include putting the sample into a humidity chamber for eight hours, moving it to the test area, rubbing the samples with a hand-held rubbing wheel to establish a charge, and then quickly moving the samples to the test equipment to read the



Electrostatic Robotic Test Cell

amount of charges accumulated on the sample.

The human error has been reduced by this project to a minimum. The accuracy, repeatability, and productivity have been increased to a level that will allow KSC to become the standard testing facility for measuring electrostatic charges on nonconductive material. The attached chart shows the improvement of the robotic electrostatic test cell over the present manual method.

H. M. Delgado, 867-3367

R. M. Howard, 867-3366

A. Pickar

DL-DED-31

DL-DED-31

DL-DED-31

ELECTROSTATIC TEST CELL PRODUCTIVITY IMPROVEMENT

	Present Method	Electrostatic Test Cell
Sample Test Time	16 Min. (Average)	1 Min., 16 Sec.
Shuttle Times	275 to 300 millisec	117 Millisec
Samples per 8-Hour Period	30 (Average)	378
Repeatability Error	13 to 20 Percent	Less Than 2 Percent
Data Acquisition Method	Manual Recording	Automatically Stored on Disk

ATMOSPHERIC SCIENCE

Meteorological and Range Safety Support System

A joint United States Air Force (USAF) and NASA project has been conducted with ENSCO, Inc., to develop a system to graphically display predicted downwind concentration profiles of locally used toxic substances, in the event of a spill. Real-time weather data is used to generate various displays of weather graphics and toxic-clear areas. The system is composed of a Tektronics minicomputer with 10MB hard-disk and ENSCO-developed software. This mini-computer system is linked to an USAF mainframe computer to receive compiled information from the local weather tower network. The equations for toxic spill prediction are empirical and were derived from tests performed in the mid-1960's to better understand diffusion of rocket propellants for local conditions.

Some of the features of the MARSS system include: menu-driven operation, on-line help displays, trajectory diffusion analysis and display, rocket exhaust cloud fallout display, distance versus concentration plots, automatic five-minute weather updates, customized high-resolution backgrounds, wind barb displays, and interpolated wind field display. Input for diffusion variables (i.e., quantities, locations, and weather) can be entered manually to predict toxic danger areas. Pre-determined variables stored for specific scenarios can be used, or the input can be a combination of both types of data to perform hypothetical analyses.

Such a system currently exists at the Cape Canaveral Air Force weather station, and future KSC efforts include a proposed installation in the firing room for Shuttle launch support.

J. R. Reynolds, 867-4317
SF-SAF

Thunderstorm Currents

The handling of propellant materials at KSC makes lightning a very hazardous phenomenon. A system that detects the potential for lightning is in operation at KSC; however, the system cannot predict whether the lightning hazard is increasing or decreasing. To do that, the state of

the thunderstorm generator itself must be determined.

Some recent developments suggest that this may be possible. Recent research in atmospheric electricity conducted by the University of Arizona Institute of Atmospheric Physics suggests that an electric-current sensor network may be able to track the state of the thunderstorm generator that produces the electricity that results in lighting.

The large arrow in the center represents the thunderstorm generator, while the contours represent current density streamlines. Since charge is conserved, the streamlines make closed loops. This fact suggests that, from an array of current sensors located on the ground, the state of the thunderstorm generator might be determined. This simplified picture may be complicated by many factors; the best way to determine whether ground-based current sensors can characterize the thunderstorm current generator is by a field experiment.

During this past summer at KSC, the University of Arizona conducted a field experiment of a limited, ground-based, current-sensor network in connection with the lightning trigger experiment. The network consisted of three thunderstorm current sensors and associated instrumentation. Preliminary results suggest that the sensors have a very high dynamic range compared to that of the existing sensors and can track the condition of the thunderstorm generator from inception to the end of the storm. Initial results are promising, and analysis of this summer's data continues. Further field testing is planned, and a more extensive network of sensors will be tested. Next year, an independent review of the research is planned, along with the development of an operational sensor.

R. P. Wesenberg, 867-4438

DL-NED-31

Clear Air-Wind Sensing Doppler Radar

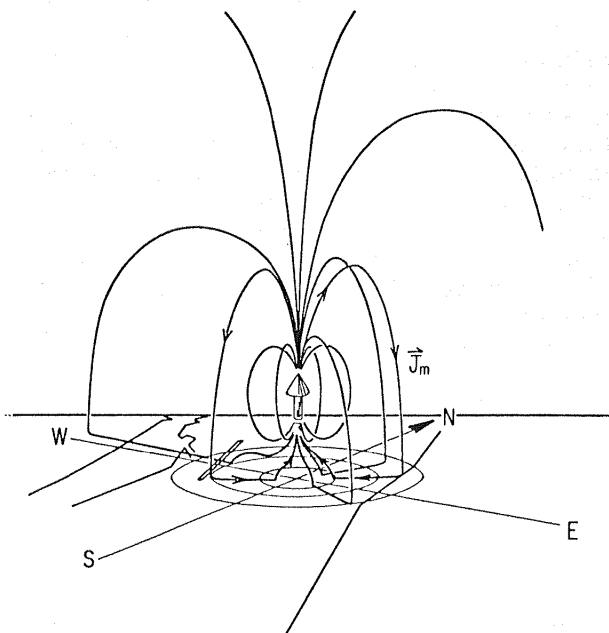
As the Shuttle launch and landing rates approach twice monthly, the effect of delays due to thunderstorms become more unbearable. A reliable 90-minute thunderstorm forecasting capability would minimize these delays, yet pro-

vide appropriate safety margins. Discussions at KSC meteorology workshops with many weather-research people suggest that clear-air wind sensing using a doppler radar may provide such a capability.

Preliminary planning and feasibility studies to test a clear-air wind-sensing doppler radar at KSC have begun. The project involves the construction of a research clear-air sensing doppler radar. The radar design would borrow much from the effort to develop the NEXRAD radar, but would be designed for clear-air sensing, rather than precipitation. The effort would include the development and testing of radar hardware and processing and control algorithms for doing clear-air work in the KSC environment, borrowing as much as possible from existing designs. This test would determine whether a clear-air wind-sensing doppler radar could, in fact, provide a reliable 90-minute thunderstorm forecast. If so, this effort would also produce a set of tested, proven processing algorithms, a performance analysis of the clear-air wind-sensing doppler radar, and a preliminary design for a working, operational clear-air wind-sensing radar system.

R. P. Wesenberg, 867-4438

DL-NED-31

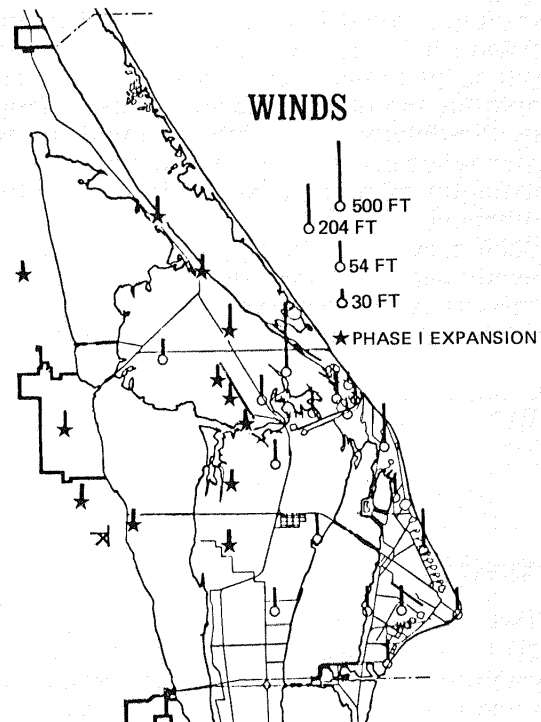


Theoretical Description of Typical Thunderstorm Generator's Structure in Terms of Current Density (J_m)

Improved Short-Term Forecasting of Lightning at KSC Based on Surface Wind Convergence

Prior research in south Florida indicated a reasonable likelihood that surface divergence could be used as a short-term predictor of lightning and activity at Kennedy Space Center (KSC) when storms formed overhead. Convergence was found to precede rainfall, and there was an indication that the magnitude of convergence was related to the amount of precipitation. These relationships varied under different atmospheric conditions. Additional research indicated well-defined correlations between radar echoes and cloud-to-ground lightning occurrence. Finally, another study in the same area showed that the amount of lightning is controlled to a degree by the larger scale synoptic controls. On the basis of these studies, it was reasonable to expect that surface convergence was related to radar reflectivities and, hence, cloud-ground lightning at KSC, especially when the synoptic scale influences were properly considered.

Data were collected in the summer of 1983, mostly during August and September. Wind data at 12 sites were analyzed at the 54-ft. level for



KSC and Cape Canaveral Air Force Station Area

surface divergence and streamline patterns. Radar data were obtained from the Daytona Beach National Weather Service radar between 1000 and 0200 hours, Greenwich Mean Time (GMT), from mid-July to the end of September, and were processed for maps and time series. Cloud-to-ground lightning data were obtained from the lightning location and protection network in the Cape Canaveral area for the same period to provide maps and time series. Three cases were analyzed in detail. One such case was the example of a 24-hour total area divergence. This case developed during a triggering operation: the Rocket Triggered Lightning Program (RTLTP) participated when deployed early enough to permit a successful triggering operation.

Surface meteorological conditions were continuously monitored by the Automatic Range Meteorological System (ARMS). For this study, 15 instrumented towers at Cape Canaveral Air Force Station and KSC were used. These meteorological stations are concentrated around launch sites and not distributed equitably throughout the area because the primary purpose of the ARMS is to monitor for the location of toxic fumes. Twelve sites provided information at 12 and 54 ft., two sites were instrumented to 204 ft., and one went 500 ft. Tower data included wind direction and speed, temperature and dewpoint, and atmospheric pressure.

Through the Weather Information Network Display System, the meteorological information

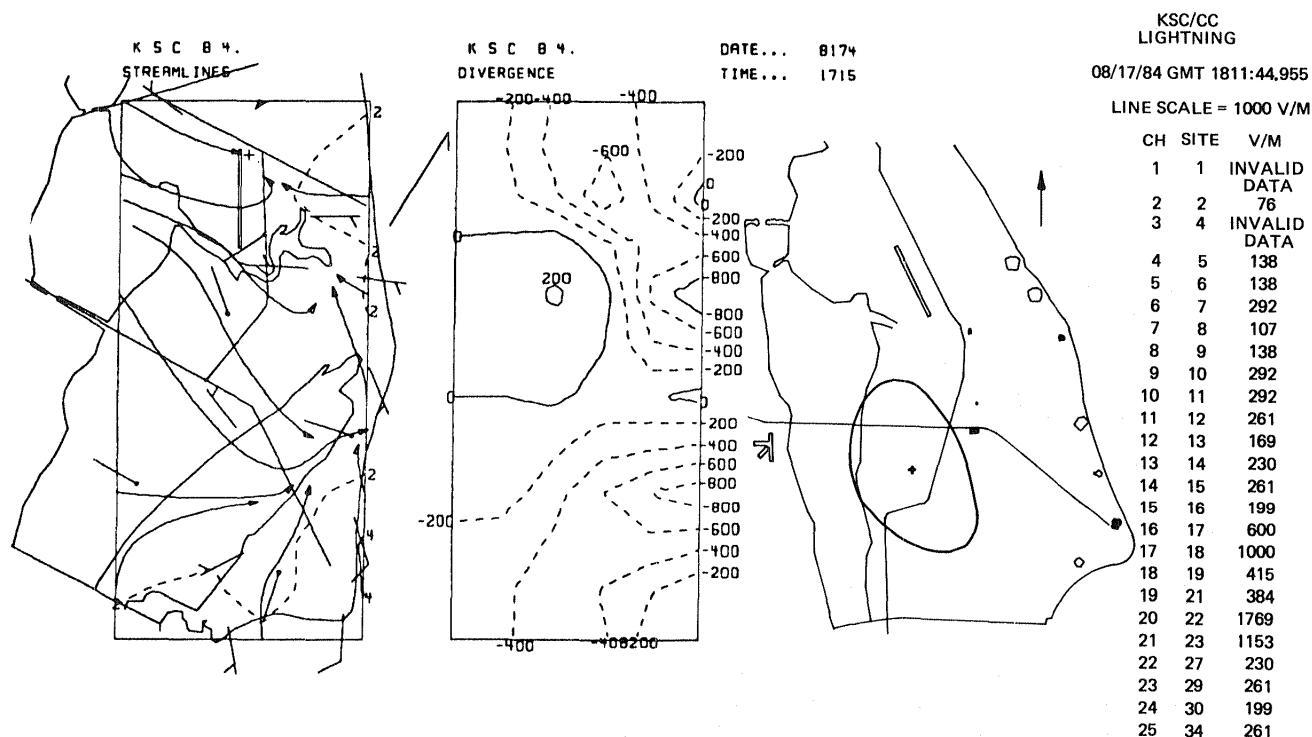
is retained on tape and provided on a real-time basis to various users at the Cape Canaveral Air Force Station and KSC. The data were kindly provided to the National Oceanic and Atmospheric Association by the United States Air Force via the Meteorological Data Reduction Section.

For the purposes of this study, the main emphasis was placed on the tower wind data recorded at 54 ft. The surface divergence fields were calculated from 5-min. averaged winds. A 6 by 12 grid of equally spaced (2.8 km) points was superimposed upon the original network. Through the use of an objective analysis scheme (Cressman, 1959), the network winds were transformed into a uniform grid of u and v components. The values of the wind components at each grid point were then used to compute the divergence quantities using a centered, finite-difference scheme.

These preliminary studies tend to indicate that it is possible to anticipate the subsequent degree of lightning activity from a measurement of prior low-level wind convergence. They also stress the need for considering not only the mesoscale situation, but the synoptic background in which the mesoscale convective processes are developing. These efforts were continued in the summer of 1985 and are expected to continue in 1986 with an expanded meso-network.

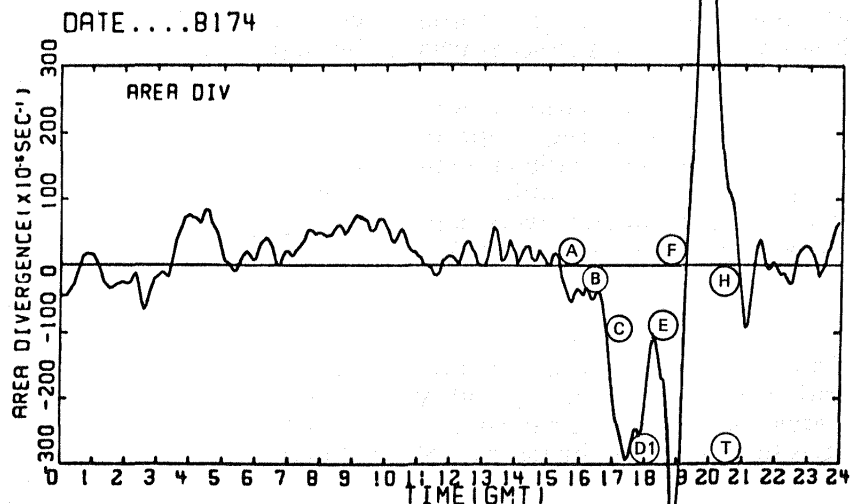
W. Jafferis, 867-3997

SO

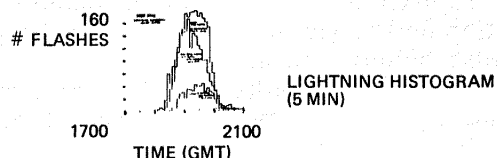


STS Launch/RTLS Weather Considerations

CLEAR SKY AT HQTS. 1515 (A) FIRST ALERT (IMPORTANCE DUE TO SOUNDING & TIME OF DAY)
 1545 (B) CONVERGENCE PERSISTS
 1635/1650 (C) SECOND ALERT (POSITIVE INDICATION OF DEV. CELL)
 1725 (D1) LIGHTNING EMINENT
 1810 (E) CELL C1 REACHES MAXIMUM INTENSITY
 1825 THUNDER 1855 (D2) CELL C2 APPROACHING N KSC RAPIDLY (INTERACTION LIKELY)
 SW-CIF STORM INTENSIFICATION EMINENT
 1826 RAIN - CIF



1915 (F) PEAK ACTIVITY (C1 + C2)
 1955 (G) END OF ACTIVE STORM NEARING
 1950 (H) STORM OVER LAST FLASH
 2003/2041 (T) ROCKET TRIGGERED LIGHTNING PERIOD 6X



AUGUST 17, 1984 THUNDERSTORM OVER KSC
 AREA DIVERGENCE CHARACTERISTICS
 2 MAJOR CELLS OCCURRED OFF KSC/CAPE AREA

STS Launch/RTLS Weather Considerations

Rocket-Triggered Lightning Program (RTLTP)

The KSC RTLTP successfully supported the Air Force Wright Aeronautical Laboratories and Federal Aviation Administration (AFWAL/FAA) Airborne Lightning Research Program this past summer. The FAA CV-580 aircraft flight operations were conducted from June 15 through August 15, 1985, with support provided by the Eastern Space and Missile Center Weather and Vector Control and KSC RTLTP according to the memorandum of understanding between NASA and the Air Force. This program was supported by noted atmospheric researchers at the University of Arizona, University of Florida, State University of New York at Albany, the Naval Research Laboratory, and the AFWAL.

The RTLTP plan was that, when a thunderstorm passed over the rocket launch site on KSC (1.2 miles northeast of the Vehicle Assembly Building), the following were performed:

1. A wire trailing rocket was launched precisely when the electric-field mill reading was optimum for triggering a lightning strike to the grounded wire (5 kilovolts per meter, minimum).
2. The FAA aircraft arrived directly over the rising rocket simultaneously with the triggered lightning strike.
3. All electromagnetic characteristics of the lightning events were photographed and recorded.

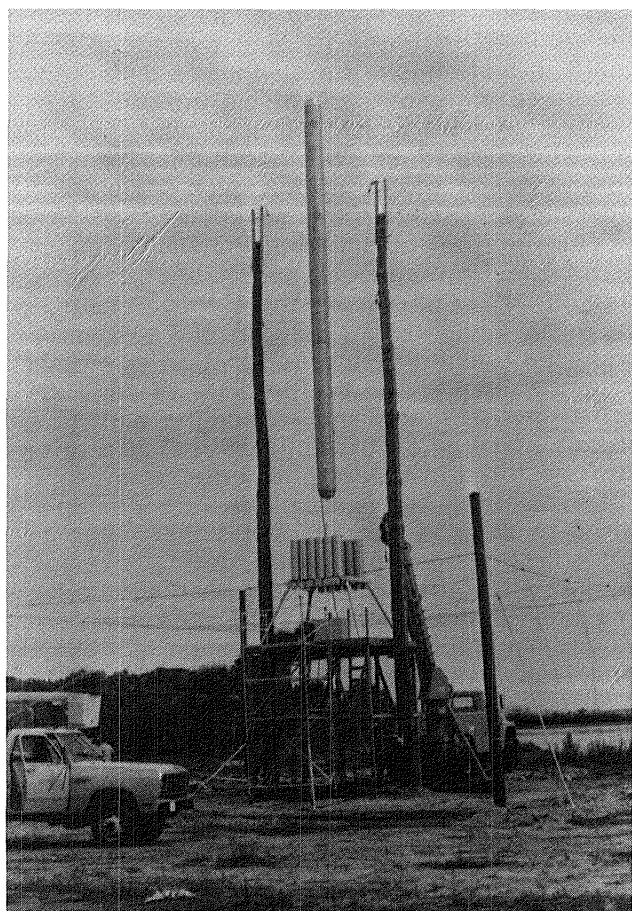
The FAA aircraft flew around many thunderstorms all across central Florida while waiting for storms to form over KSC. Substantial ground

and airborne electromagnetic and current data were obtained from 22 natural lightning (primarily intercloud) strikes to the aircraft. Two of the events may have been natural cloud-to-ground lightning events. RTLP produced 34 rocket-triggered lightning events. Significant data were collected by the aircraft and ground instrumentation during these events. The RTLP ran for 78 days from June 15 through August 31, 1985. Fifty-eight rockets were fired during the 13 thunderstorms that developed near the rocket site. The triggered-lightning events did not hit the aircraft, even though the aircraft was vec-

tored on target at the site. Many of these events were captured on video tape and film. Preparations are underway to produce a documentary video tape of the summer activity.

W. Jafferis, 867-3997

SO



1985 Rocket-Triggered Lightning Site

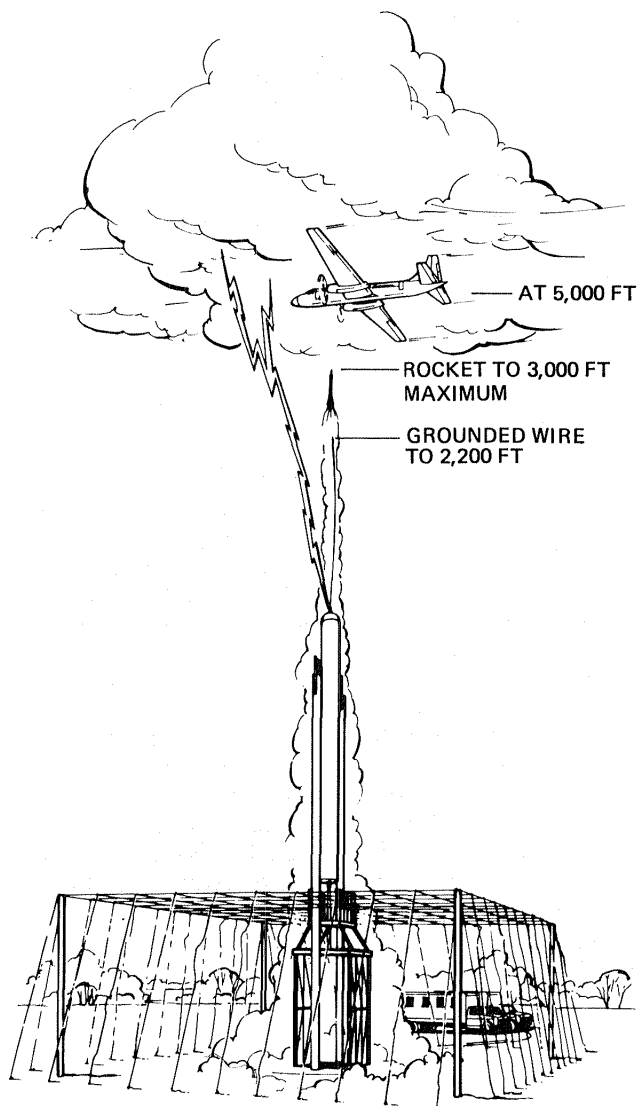


Illustration of RTLP Experiment

EXPERT SYSTEMS

Expert Planning and Scheduling Systems

At the Kennedy Space Center (KSC), science and applications payloads are processed through a number of steps before they fly as part of an integrated Space Shuttle payload. Individual experiments are received at the Operations and Checkout (O&C) Building in the KSC Industrial Area. Following inspection and preparation in support areas, payload elements begin an assembly-line-like process that brings them together to form a compatible, functioning payload unit. Each phase of integration — experiment integration and Spacelab integration — results in a progressively more complete, functional flight payload. As can be imagined, planning and scheduling is an important part of this process. As a result, two expert systems are being developed to enhance existing capabilities. One is Expert Mission Planning and Replanning Scheduling System (EMPRESS), the other is Planning Network (PLANNET). In time, both systems may become integrated.

EMPRESS is a prototype Artificial Intelligence (AI) expert system being developed jointly by NASA-KSC and the MITRE Corporation of Bedford, MA. The main objective of EMPRESS is to provide a system which utilizes the tools and problem-solving heuristics (rules) employed by a planning and scheduling expert at NASA-KSC in constructing and maintaining mission schedules — at the top level — called the Master-Multi Flow (MMF). EMPRESS supports the KSC planner in planning schedule activities by defining the time, resource, and task requirements associated with processing a payload manifested to fly on the Space Shuttle. Furthermore, EMPRESS supports the KSC planner in the replanning of schedules contained in the MMF caused by changes from outside sources or by internal problems, that is, resource requirements which constrain scheduled activities.

Since the NASA Headquarters prepared Manifest, which identifies the payloads to fly on Space Transportation System (STS) missions, changes frequently, and since payload processing can vary greatly from payload to payload, the environment in which payloads are processed is a dynamic one. To monitor and control this environment and to ensure a capability to process multiple payloads simultaneously, KSC generates and maintains a schedule hierarchy.

The Master-Multi Flow (MMF) is one of these schedules. It provides information on the status (planned or actual) of major processing activities of manifested Spacelab-like, attached payloads. It is updated regularly to reflect changes in a Manifest, and enable the planner to detect any scheduling or resource conflicts introduced by Manifest changes which will necessitate replanning and subsequent rescheduling of one or more payloads. EMPRESS has been designed to generate and maintain this schedule.

The principal objective of PLANNET (developed by McDonnell Douglas Astronautics-KSC with initial support from the Georgia Tech — Engineering Experiment Station), was to demonstrate the feasibility and application of expert system technology to the problem of daily 72-hour/11-day planning and scheduling activities, including facility/resource utilization. The project effort resulted in creating and documenting a prototype of this application. The ultimate objective is to support overall operational planning and scheduling. The initial demonstration requirement addressed only a subset of the planning and scheduling activities; work will continue to expand the prototype system to make it more realistic, than speculative.

In addition to ascertaining the existence of constraints between newly manifested mission payloads and supporting short-term payload-processing activities, EMPRESS and PLANNET will be used to assess the impact of possible changes or hypothetical situations. In this role, these systems will serve as a method for identifying constraints and exploring alternative paths for resolution. One of the prime objectives of this technological application is to provide this function, along with sophisticated capabilities to detect conflicts, which usually necessitate the replanning of activities.

J. M. Ragusa, 867-7882
J. Dumoulin, 867-3466
K. Wetzel, 867-3750

CS-SED
CS-SED-21
CS

Machine Learning and Control

As part of KSC's Knowledge-Based Automatic Test Equipment (KATE) project, LISP code has been written, which can automatically infer the structure of simple black-box circuits. After testing the circuit via a commercial real-world interface and building a table of corresponding inputs and outputs, KATE is able to build a knowledge-base which is used for drawing the circuit diagram on a CRT and for monitoring, diagnosing, and controlling the circuit. This is called learning from observed performance, and has direct application to the automatic creation of knowledge-bases for control and monitor of hardware systems. To date, the system has been demon-

strated on simple digital logic circuits and a partial implementation for analog circuits. Control of the circuit has been demonstrated by the use of goal-oriented functions that search the knowledge-base for commands that can be changed to produce a desired output. All possible combinations of commands are presented as options to the operator to meet his goal. This command technique eliminates the need for low-level canned procedures for component control. The KATE project will continue throughout 1987 at KSC to develop a complete automatic testing system for black-box devices.

E. E. New and M. Cornell, 867-0797
SE-ETD-22, SE-ETD-21

Controlled Environment Life Support System (CELSS) Breadboard Project

A major project was initiated at Kennedy Space Center (KSC) in 1985 with a goal of integrating biological regenerative life-support systems within a large chamber at a scale sufficient to adequately test their performance for use in long duration spaceflight. The concept of a CELSS is not new. Most available data indicate that the problems with the long-term presence of man in space are those associated with life support systems, rather than the mechanical integrity engineered into the vehicles. As the duration of missions in space becomes longer and longer — many months to years — construction of an integrated reliable life-support system incorporating regeneration becomes increasingly crucial.

The first step in a sequence of activities planned for this project: to design, construct, and operate a sealed (gas, liquid, and solid) plant growth chamber, was initiated this year. This chamber, 24 ft. tall by 12 ft. in diameter, is mounted on legs with the central axis vertical. Entrance to the chamber is through an air lock. It is located in hangar L, KSC, and will be devoted entirely to higher plant experimentation. Waste management, food processing, and product storage will be carried on outside of the chamber.

A detailed set of specifications for design was assembled at KSC based on all the facts available. Because of the need to grow many different crops, the essential growth parameters will be adjustable over a wide range. Radiation (light), for example, will be adjustable from off to about $\frac{1}{2}$ of sunlight over the plant beds. The level of $1000 \text{ umole m}^{-2} \text{ s}^{-1}$ of photosynthetically active radiation (400-700 nm) will provide the irradiance which many candidate crops such as wheat, potatoes, soybeans, and rice need for optimum performance. Chamber temperature will be adjustable from 16°C to 30°C with an accompanying relative humidity range of 60 to 70 percent.

Carbon dioxide and oxygen will be monitored continuously, and controlled to maintain oxygen at 21 percent and carbon dioxide from atmospheric to 2500 parts per million (ppm). A slight positive pressure in the chamber will facilitate control and volumetric measurement of make-up gases and air loss.

Air circulation throughout the chamber and over the plant beds will be adequate to maintain temperature and provide essential gas and moisture exchange. Transpired moisture estimated to approach 250L (500 lb.) per day will be condensed by the air conditioning system, then measured and analyzed. Later in the program, the moisture will be processed and returned to the nutrient solution.

A manual control system for lighting, temperature, moisture, and other variables will be installed initially. Later, upgrade will include computer monitoring and control for all environmental parameters, pressure regulation, and safety features.

Data acquisition will begin with monitoring chamber and plant conditions by computer. This will include processing and data file management. These will permit analysis of growth rates, thermal analysis, and evaluation of energy inputs.

The first of a number of experiments, to be initiated in March 1986, will consist of monitoring all variables while growing a crop (for example, beans or wheat). Tests of multiple species will be conducted once confidence has been gained with single species.

The chamber design will permit evaluation of plant spacing mechanisms to increase yield and maximize light utilization for continuous production systems, as well as for growing many species in an open environmental chamber. Additional tests will permit evaluation of different schemes to improve volume utilization.

The development of this biomass production subsystem will be closely tied to the design and capabilities of the sealed chamber. As experience is gained, the chamber will be adapted to eliminate or control problems expected with changes in the atmospheric gas composition, nutrient and water utilization, and possible microbiological contamination. Hydroponic plant growth techniques have been selected as most appropriate for a closed, recycling CELSS system. A conventional hydroponic system will be used initially in the closed chamber to allow examination of the effects of closure, without the possible complications in data interpretation imposed by less tested units. Several less conventional hydroponic system types are currently being investigated for subsequent use, including the Capillary Effect Root Environment System (CERES). This nutrient film technique system is currently under development for possible testing in the middeck

of the Shuttle. Other hydroponic systems that are adaptable to microgravity, use low water volume, and minimize microbial contamination will be developed and tested.

W. M. Knott, 867-3152

MD-ENV

Multispectral Analysis of Nuclear Magnetic Resonance (NMR) Imagery

Kennedy Space Center (KSC), Washington University in St. Louis, Missouri, and the University of Florida are working jointly on pioneering research with Nuclear Magnetic Resonance (NMR) imagery. NMR is a new medical diagnostic tool that has great potential for solving medical problems that currently have no solution. KSC and University of Florida engineers are applying NASA multispectral image processing technology for the purpose of analyzing NMR medical data obtained from Washington University's Mallinckrodt Institute of Radiology physicians.

Private industry, including Siemens Company, General Electric, and McDonnell Douglas, are very much interested in this activity and are monitoring the progress for applicability to their commercial NMR systems.

NMR imagery includes sets of data for proton density and relaxation times that are in registration for multiple sections through an organ or body region of interest. An analogy exists between satellite imagery and simultaneous sets of NMR images at the same anatomic level with different contrasts (e.g., proton density, T_1 and T_2).

Satellite images, such as those from the LANDSAT, are available in sets where the elements of each set are individual frames of visible light, near infrared, far infrared, and others. Advanced image processing systems for the analysis of satellite data have been constructed by NASA and others.

Simultaneous sets of NMR data (proton density, T_1 and T_2) have been converted into a format that is compatible with a satellite image processing system (General Electric Image 100) owned by NASA and operated by the University of Florida. The analysis of these NMR data with the image processing system allows summarizing of the contrasts present in each individual NMR section into a single color image that contains the important contrast information from each of the elements. In this manner, the image processing

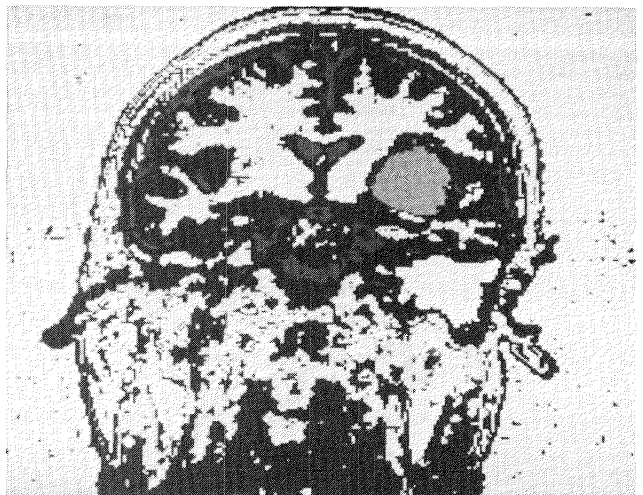
system can form a single image containing the important information from three or more separate images of the same section. For example, at a given slice location in the brain, a single color image (with near-true color) can be constructed by combining the proton density, T_1 and T_2 , images at the same anatomic location.

A computer-generated multispectral classification of the important features can also be constructed. For example, a green signature area is a hematoma, a light-blue area is white matter, and a dark-blue area is cerebral-spinal fluid.

Activities during the last year were directed at further refinement and application of these techniques. Both the Earth Resources Laboratory, of



*Single Image Containing Important Information
from Three or More Separate Images of the Same
Section of the Brain*



*Computer-Generated Multispectral Classification
of Important Features of the Brain*

the National Space Technology Laboratories in Bay St. Louis, Mississippi, and the Jet Propulsion Laboratory in Pasadena, California, became involved with the project to support this. The Mallinckrodt Institute of Radiology at Washington University was enhanced in image-processing capability this year, with KSC consultation; for example, the applications software image analysis program from the Earth Resources Laboratory was delivered to Washington University.

This past year, KSC has placed a computer tomography (CT) scanner in a non-destructive

testing laboratory next to the launch pad. It is being used in a variety of applications — for example, to locate problems and defects in the fuel pump and protection system tiles of the vehicle.

Future activities include optimization of NMR scanner setup parameters, determination of the best image classification schemes for specific diseases, and application of these techniques to larger number of cases.

R. L. Butterfield, 867-3017

PT-TPO

OPERATIONS

PRACA-Based Prediction

A feasibility study is being conducted by EG&G ENTEC Division to determine the practicality of using expert systems with the Problem Reporting and Corrective Action (PRACA) data base for trend predictions to improve reliability, quality, and safety of systems at KSC.

The PRACA system is used at KSC to document anomaly conditions associated with launch processing of spaceflight hardware. The information recorded on forms is placed in a Honeywell mainframe computer data base for batch retrieval and entry functions by systems operators.

The efforts that have been accomplished thus far include: down loading data from the mainframe computer in batch form to an IBM PC microcomputer via communications software, reformatting the data for PC data base management, and using a natural language shell to exercise trending analysis on the data base. These efforts have demonstrated some key tasks that could improve the overall usability and relationship between the PRACA system and its users.

The final phase of the study will involve downloading an operational subset of data and developing a limited knowledge/expert representation and techniques for trend analyses.

J. R. Hankins, 867-4493

SF-ENG

KSC Avionics Test Set

As the Shuttle program has matured and test consoles and avionics equipment have become available, Kennedy Space Center (KSC) investigated the feasibility of establishing a low-cost integrated avionics facility at KSC. It would be able to be connected to at least one of the firing rooms and use existing or upgraded math models to simulate many of the Orbiter systems. This capability was deemed necessary for the following reasons:

1. It will enable ground software debugging and verification to be done at KSC, rather than sending people to Shuttle Avionics Integration Laboratory (SAIL) at Johnson Space Center (JSC).

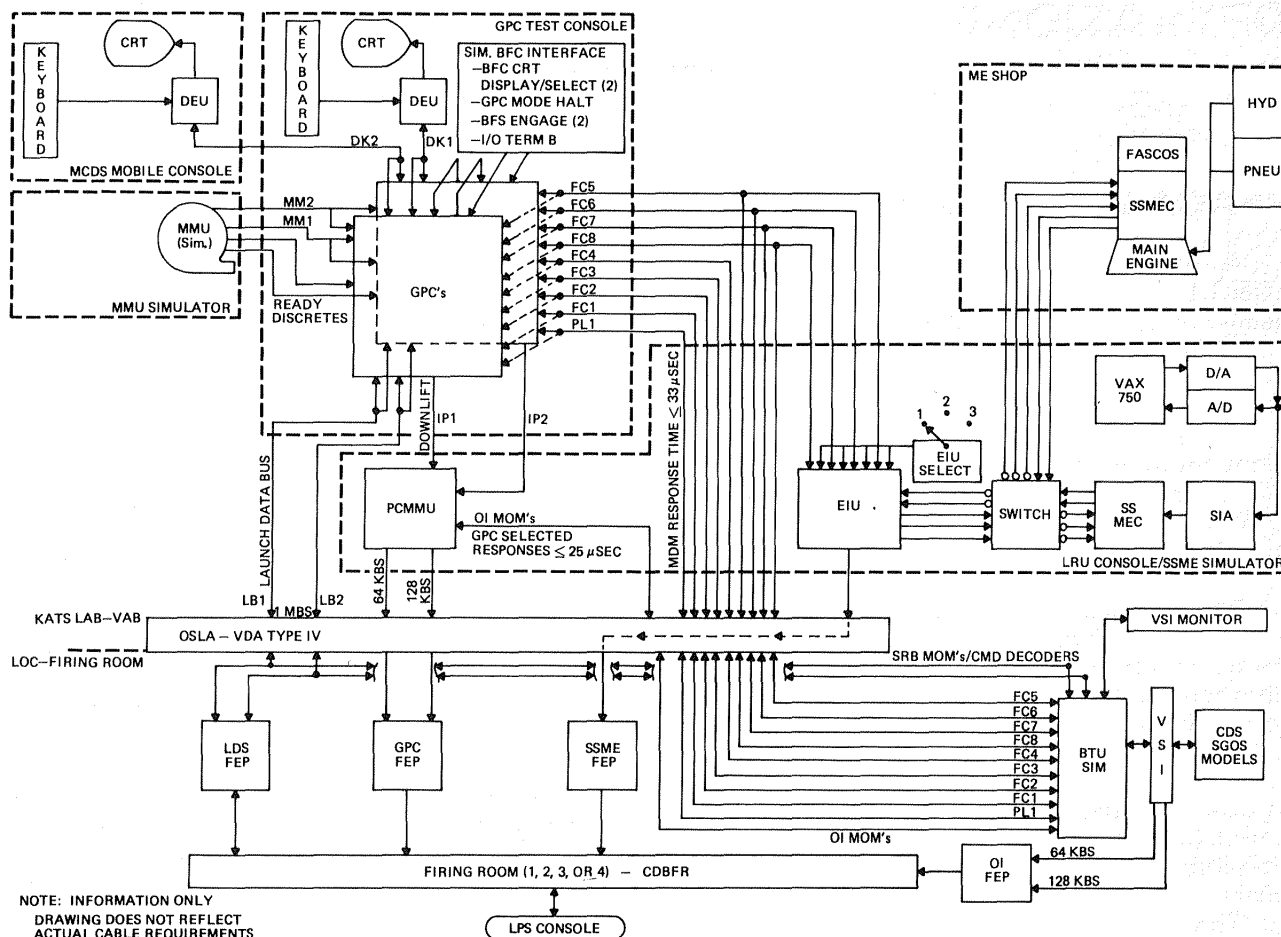
2. It will provide for periodic and preinstallation testing capability of many of the Orbiter's Line Replaceable Units (LRU's).
3. It will integrate terminal countdown and system training.
4. It will aid dry-run procedures.
5. It will troubleshoot Orbiter problems.
6. It will provide the interface to checkout a spare Space Shuttle Main Engine (SSME) in the Main Engine (ME) shop.

With the above rationale and goals in mind, the KSC Avionics Test Set (KATS) was conceived and approved by Level I in September 1983. The KATS operational target date is December 1, 1986. The KATS consists of an integrated set of avionics hardware, simulators, and test consoles. Special hardware was built in the Launch Processing System (LPS) that simulates the Orbiter Multiplexers/Demultiplexers (MDM's) and Engine Interface Units (EIU's) and allows the KATS (GPC's) to interface with the math models to obtain system information. The following LRU's will be housed in the KATS (see the figure, "KATS"):

1. Two GPC's
2. Two MCDS's
3. One MMU
4. One EIU
5. One PCMMU
6. One SSMEC
7. Two BFC's

The Backup Flight System (BFS) Test Console used at Downey was modified for KSC, and provides control and houses the General Purpose Computers (GPC's), Backup Flight Controllers (BFC's), and Maintenance Control & Display System (MCDS) equipment. A rack was built at KSC which houses the Pulse Code Modulation Master Unit (PCMMU), EIU, and Mass Memory Unit (MMU). This rack provides the capability to identify the EIU as being EIU 1, 2, or 3, and to connect it to the Space Shuttle Main Engine Controller (SSMEC) on the spare engine in the ME shop or the SSMEC in KATS.

The SSME simulation consists of a Rocketdyne-built Simulation Interface Adapter and VAX 11/750 which executes a dynamic model of the SSME in all phases. The interfaces to the LPS are provided by an Orbiter/LPS Signal Adapter



KATS

(OLSA) rack in the KATS, which consists of two Launch Data Buses (LDB's), Orbiter Instrumentation (OI) Data Bus, eight flight-critical data buses, two payload data buses, a 128-Kb data link and a 60-Kb data link. The facility has fault insertion capabilities to simulate real vehicle failures, which provides an excellent training tool, and an aid in recreating vehicle problems.

The KATS will provide KSC with a more efficient launch team, higher reliability ground software, and higher confidence levels in spares installed in the vehicle. The KATS definitely will be a contributing factor to the operational aspects of the Space Transportation System (STS) program in the future.



KATS in the Vehicle Assembly Building

M. O'Neal, 867-6210

SE-GDS-23

Voice Activated Computer Utilization

With the advent of relatively inexpensive voice recognition units, experimentation has begun at Kennedy Space Center (KSC) into possible applications for voice control of computers. The objective is to demonstrate the potential for voice-actuated computers for those whose jobs require busy hands/busy eyes, as well as for the physically handicapped or otherwise physically limited persons. Some potential applications are supply warehouse workers taking inventory or a Space Station construction worker, with hands full, controlling a Manned Maneuvering Unit by voice.

The hardware configuration used in this research consists of an IBM PC/XT with a plug-in voice recognition unit manufactured by Votan, and a 3270-type terminal emulator (used to communicate with a mainframe computer), manufactured by Digital Communications Associates. Also used were several popular software application programs, including a Lotus 1-2-3 spreadsheet, an Easy Writer word-processor, an IBM Professional Editor, Basic, a Macro assembler, Debug (an assembly language monitor), as well as the software used to drive the terminal emulator.

Initial voice control testing of the IBM PC/XT software has proven successful. However, it was discovered that the terminal emulator microcomputer to mainframe connection would not respond to voice commands. This problem was overcome by modifying the emulator assembly language software to accept voice commands.

As an example of the practical use of voice control, a demonstration has been set up that performs one of our monitor functions. The task requires the user to log on a mainframe computer, access a file of data on the mainframe, download this data to a file on the PC, pull this file into a spreadsheet, and graph the result, all under voice control without touching the keyboard. This task has been successfully accomplished using only 23 voice commands, which includes setting up the double-lined graph representing two sets of data, complete with titles, legends, and other options, all of which would normally require 250 keystroke entries.

Since one voice command can represent many keystrokes and/or instructions, the above procedure was accomplished faster by voice (by a factor of 10), than be the manual keyboard entry method. In any repetitive task, time savings can be achieved, as well as an improvement in accuracy of data entry.

This project has demonstrated that voice control is especially well-suited for the input of

highly complex commands, voluminous data entry, or applications where keyboard entry is awkward. A voice recognition unit attached to a microcomputer equipped with a hard disk drive, sufficient memory, and the proper selection of applications software has the potential of becoming an excellent desk productivity tool. Likewise, special hardware configurations can be used for more specialized tasks.

L. D. Fair, Jr., 867-7040

SI-CSD-2

Simulation of the Space Station Logistics Module Turnaround Processing Flow

The Logistics Module (LM), a cylindrical vessel approximately 30-ft. long by 14-ft. diameter, is a Space Station (SS) element used to resupply the SS with required consumables, expendables, payloads, and spares. The LM nominally will be transported to the SS every 90 days and exchanged with the LM, depleted of supplies and carrying wastes. The depleted LM will be returned to earth for ground processing and repair in preparation for resupply missions. The LM shell is the same as other SS modules (lab modules and habitability modules), except that a radial port segment is replaced by the internally mounted tankage segment. The SS program is planning to manufacture two LM's for supporting on-orbit operations: one on-orbit and one in ground processing.

The LM is the SS element most sensitive to planning and scheduling changes. Any significant perturbations or ground processing delays for the LM will have a direct effect on the orbiting SS. In addition, the LM processing at the launch site represents the single most significant function for KSC in the SS program in terms of processing capabilities, on-going operations, and overall costs.

Options and alternatives for SS LM processing need to be evaluated carefully to effect optimum and orderly implementation planning. Consequently, the Space Station Operations Model (SSOM) will allow testing of the processing flow of the SS LM; so that time and resource parameters may be varied, operational, schedules assessed, and processing functions optimized.

The objective of the SSOM project is to construct an analysis tool which would enable operations personnel to test scenarios, determine critical/sensitive tasks and resources, and aid in

the design and processing of the SS LM.

The process of simulation modeling was chosen as the approach for the LM analysis tool, based on its flexibility, speed, cost effectiveness, and potential for future expansion.

To ensure that the developed simulation model would be understood and utilized, project goals were set, including: ease of running and modifying the model, user-friendly data input, fast response to user queries, and understandable and adaptable model output.

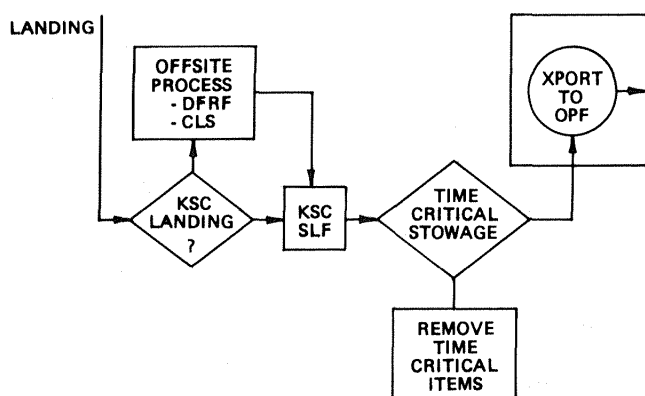
A user-friendly, menu-driven preprocessor program was developed to help meet these goals.

The preprocessor created for the SSOM project was built in the standard FORTRAN 77 computer language. This was chosen due to its wide transportability on numerous computer systems.

The preprocessor was built to be friendly to model operators who know little about computers, and efficient to operators requiring input data changes. To achieve this, a "menu-format" interface was built. Operators are asked questions in menu form. Answering these questions in sequence will make all necessary input changes and will run the model.

The simulation model developed for the SSOM project will benefit design and operations personnel by providing a methodical analysis tool for LM processing. Benefits include the ability to:

1. Analyze critical processing flow tasks and ground support equipment (GSE) availability issues
2. Analyze time and manpower effects of different design issues (that is, removable versus fixed waste module)
3. Predict KSC facility and overall timeliness to process the LM in a manner consistent with the changing conditions at KSC (delays, hardware problems, and others)

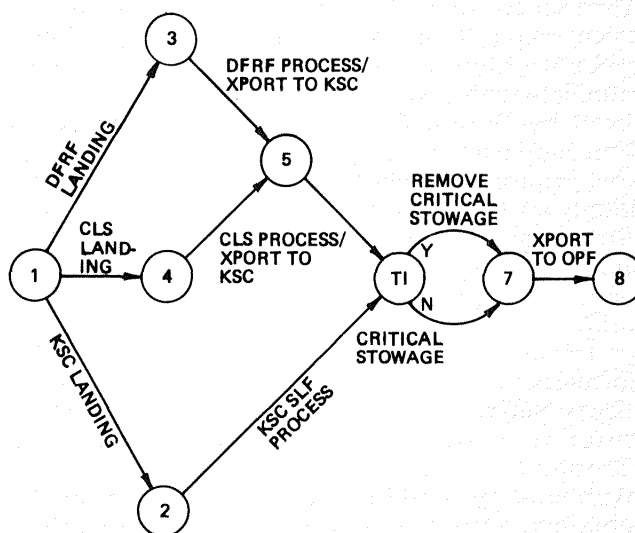


Shuttle Landing Site (SLF) Logic Flow Diagram

Decision points and potential processing delays have been identified in the LM resupply processing flow to permit modeling of various hardware and support equipment availabilities and processing contingencies. The user can define the probabilities of the various processing paths for each of the decision points or use baseline data, resident in the preprocessor.

The LM Turnaround model has the following capabilities:

1. Analysis of processing flow delays and timeliness
2. Analysis or processing flow manpower loading and constraints
3. Analysis of LM design options
4. Ability to input GSE availabilities



Shuttle Landing Site (SLF) PERT-Type Network Diagram

To create the model, the LM processing flow (the figure, "Shuttle Landing Site (SLS) Logic Flow Diagram" illustrates one segment of this flow) had to be developed. From this, the PERT-type network depiction of the LM Turnaround flow (see the figure, "Shuttle Landing Site (SLS) PERT-Type Network Diagram") was derived. There are five facilities necessary to process the LM at KSC. These each required a network depiction and include:

1. Shuttle Landing Facility (SLF)
2. Orbiter Processing Facility (OPF)
3. Space Station Facility (SSF)
4. Vehicle Assembly Building (VAB)
5. Launch Pad (PAD)

The LM Turnaround Model is actually created as two separate models: one a deterministic or

"what-if" model, and the other a probabilistic or "performance indicator" model. Each is discussed below.

The deterministic version of the LM Turn-around Model allows operations personnel to pose "what-if" processing flow questions to the model in order to determine answers to common problems. For example:

1. What if we have a delay in a specific task; how does this affect my 90-day processing flow requirement?
2. What if I put more manpower on a specific task; how does this affect my requirement?

This version is simply a network model of the LM processing flow, and it calculates processing times based on the complex serial and parallel tasks occurring in the processing flow. The model goes through only one iteration and allows for instant determination of processing time and manpower requirement questions.

The probabilistic version of the LM Turn-around Model simulates multiple runs of the processing flow and looks at probability distributions for task time requirements. As a result, a mixture of best, worst, and most-likely times will be statistically sampled and will reflect a real-problem situation. For example, sometimes (not often) a specific task will be completed in the best time of five days. Sometimes it can also be completed in the worst time of 10 days. However, more than likely, it will occur in seven days, and a probability distribution can be fitted to these values. Over many iterations of the model, any number from this distribution (a simple triangular distribution) can be statistically selected and a cumulative probability curve can be built. This cumulative probability curve, also called a performance curve, can give the operational user the probability that a specific task will be completed in a certain amount of time.

Useful tools for the analysis of complex and repeating operations are necessary in the SS program to ensure a cost-efficient and safe orbiting national resource. Engineering resources, such as simulation and operations research tools, will answer many of the pressing SS questions, prior to launch.

R. W. Tilley, 867-4176

SS-OCO

Documentation Management System

The management of documentation in support of advanced space systems has been and

will continue to be, an expensive and difficult task. This is especially true when Space Station on-orbit considerations are integrated with ground processing documentation requirements. An ongoing effort has been underway to identify an automated baseline system that will be cost-effective and efficient, as well as being responsive to the individual needs of the user community and providing effective management overview. Tasks to date have been in the following areas:

1. Document number assignment/accounting
2. Hazardous/non-hazardous documentation control
3. Status of assigned documentation
4. Documentation storage and distribution

Current efforts involve use of a stand alone PC programmed to produce 13 reports. Future efforts will include networking the use of the data base and providing direct user access, inquiry, and update capability.

T. Mariani, 867-4861

CS-CSO-1

Technology Assessment for the Dynamic Resource Development/Allocation Model for Spacecraft Processing

Model description: The Dynamic Resource Development/Allocation Model (DRDAM) is a computer simulation model that represents the interactions of requirements and resources for processing manned spacecraft at Kennedy Space Center (KSC). The model uses a continuous state-variable feedback systems paradigm to trace the performance implications of a given set of processing policies and resources over a medium-term time span (one-10 years). DRDAM links the requirements for launch services at KSC and Vandenberg Air Force Base (VABF) with the personnel and major processing facility resources at KSC. It translates the launch dates and payload characteristics into feasible processing and launch schedules, given the utilization status of resources in the processing system. Specific processing times reflect empirically estimated learning curves and the types of payloads.

DRDAM simulates the flow of primary spacecraft elements through the Orbiter Processing Facility (OPF), Vehicle Assembly Building Facility (VAB), and launch pads. It coordinates the alloca-

tion of personnel of various skill categories between facilities with the overtime and shift discipline in each activity required to meet the processing schedule. It tracks Orbiters from KSC or VAFB launches to return to KSC for processing, via alternative landing sites. It also incorporates the activities required to deliver the external tanks (ET's) and solid rocket booster (SRB) segments to KSC to maintain processing flows.

Besides simulating processing activities, DRDAM includes logic to determine manpower requirements and manage the hiring or separation of personnel by skill categories. Manpower requirements computations reflect the addition of new facilities, planned launch schedule density, the ability of the system to adhere to the launch schedule, and the evolution of the processing skill mix over the simulated time horizon.

The structure of DRDAM allows monitoring of processing-system performance in terms of activity levels, resource consumption, schedule adherence, and cost flows on a daily basis over the simulated time span.

Technological advances: DRDAM represents an analytical advance because it expands the time span and breadth of spacecraft processing activities incorporated into a unified modeling framework. The diversity of integrated elements provides the basis for the consistent analysis of a new range of issues and policies that will evolve over the next two decades, such as:

1. The affects of learning curves on processing costs, feasible launch cycle times, schedule adherence, and manpower requirements
2. The effects of VAFB manpower support on KSC processing capacity
3. The effects of stationizing the workforce on schedule adherence and processing costs

4. Contingency assessments for temporary losses of major capital assets, such as Orbiters, SRB or ET transport, or mobile launcher platforms (MLP's)

5. The impact of the interaction of launch schedule acceleration and alternative workforce buildup strategies on processing system performance

The code for the DRDAM prototype was developed on a VAX 11/780 in a mainframe version of DYNAMO III/F — a language suited to the simulation of continuous closed-loop feedback systems. The operational version of DRDAM is being implemented on an enhanced IBM microcomputer system, using a new DYNAMO compiler currently in the final stages of beta test development. This implementation will test the feasibility of using low-cost microcomputers for large scale (more than 1,000 non-linear equations) simulation analysis.

The employment of a single-user workstation and the advanced host software environment will promote a new degree of efficiency in user interaction with complex models in scenario construction, and in the analysis and communication of results. Simulation results will be displayed with high resolution pixel graphics, and the user can fully specify the formats for printed reports. Moreover, future releases of the microcomputer version of the DYNAMO software system will offer a multiple parameter search capability that will allow rigorous policy optimization analysis for a given set of system constraints and objectives.

J. McBrearty, 867-4646

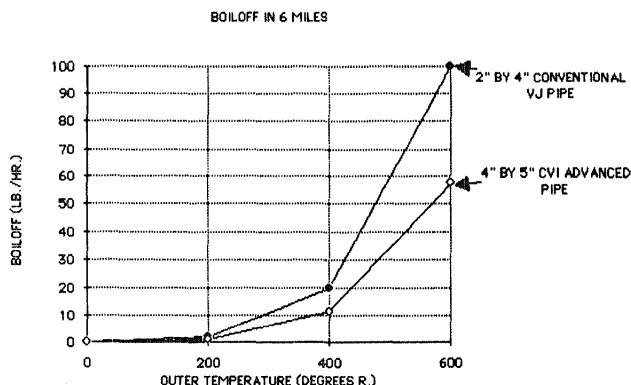
SM-ANA

TERRESTRIAL ENERGY

Conceptual Development of a Polygeneration Advanced Liquid Hydrogen Transfer Line

Plans have been underway at Kennedy Space Center (KSC) to install a polygeneration plant to manufacture liquid hydrogen, liquid oxygen, gaseous nitrogen, and electricity from a coal gasification process. The plant is to be installed approximately 5½ mi. from Shuttle launch pads A and B. Experience has shown the boiloff losses from loading liquid hydrogen off trailer transporters to pad storage tanks to be as high as 14 percent of the hydrogen delivered. This finding lead to the idea of installing a liquid hydrogen transfer line from the plant to the pads.

The initial investigation was made on a conventional vacuum-jacketed transfer line. Calculations of boiloff resulting from heat transfer and fluid-flow friction heat input showed the boiloff to be a minimum of 22 percent, with the optimum line sizing of the transfer lines. This lead to an evaluation of a radiation barrier shielded line being developed by CVI, Inc. This pipe uses an aluminum radiation heat transfer shield that is chilled by vented hydrogen boiloff into tubing in the vacuum between the inner and outer pipe. Dr. Han Chang, in connection with Montana College of Mineral Science and Technology, performed a conceptual analysis of this line. Calculations showed acceptable heat transfer from this pipe. Heat transfer through this advanced design as compared to the conventional pipe is shown in the figure, "Comparison of Heat Transfer Rates."



Comparison of Heat Transfer Rates

The results of this analysis show the total boiloff of the transfer line to be only 7 percent. Plans are being made now to procure a section of this pipe and run boiloff tests to compare calculation results with test data.

F. S. Howard, 867-3202
DD-MED-4

Heat Pipe Heat Exchanger Dehumidification Coupled to Solar Air Conditioner

Early marketplace introduction of heat pipe-heat exchangers (HP-HX) that increase dehumidification rate of residential air conditioners has been coupled to a novel solar photovoltaic (PV)-powered air conditioner. Dinh Company of Alachua, Florida has developed a highly efficient PV-powered air conditioner. Models have dc motors to use the PV-developed power without losses attributed to power conditioning. Backup power from residential grid connection is converted to dc for periods of no isolation. Air-to-air, water-to-air, and earth-coupled designs have been developed in several capacity ratings. NASA is assisting in the transfer of HP-HX and PV-powered technologies to the air-conditioning industry.

The HP-HX is available as an option on the various models and in other designs as a retrofit for standard models of other manufacturers' non-solar air conditioners. The HP-HX dehumidification application was suggested by Dinh and established as feasible through studies principally conducted by the Florida Solar Energy Center. The HP-HX is an effective way of enhancing the moisture (latent heat) removal rate of present day "high EER" air conditioners to make them match the demands of residences in warm humid climates, well-insulated homes, and some small commercial situations where internal moisture generation causes removal problems.

W. H. Boggs, 867-2133

DD-FED

Polygeneration

Polygeneration is an innovative approach to reducing cost for energy-intensive propellants and consumables used in the Space Shuttle Program at Kennedy Space Center (KSC). For about four years, the KSC Engineering Development Directorate has had a project team investigating the economic and technical feasibility of the polygeneration approach. Polygeneration describes a process that will produce liquid hydrogen (LH₂), gaseous and liquid nitrogen (GN₂ and LN₂), liquid oxygen (LO₂), and electricity from an integrated, coal-gasification, combined-cycle (IGCC) power plant. A key cost-savings element of the polygeneration approach is the production of high-value products using the least costly feedstock — high sulfur coal — with the maximum integration and utilization of byproducts. Another side benefit of the project is the commercial demonstration of coal-utilization technology with proven potential to reduce purported acid-rain-causing pollutants by one to two orders of magnitude over existing state-of-the-art technology in use by the power industry.

Presently, the design feasibility stage of the project is completed and is being reviewed by NASA management, prior to a decision to proceed with implementation. The project may be implemented by either NASA or by the private sector.

The coal-gasification and gas-cleanup system gasifies the input coal and cleans up the output gas to produce a clean, medium-Btu gas composed primarily of carbon monoxide (CO) and hydrogen (H₂). It has a Btu content of approximately 270 Btu's per standard ft³, compared to natural gas, which has about 1,000 Btu's per standard ft³. Sulfur compounds can be readily extracted from this product gas stream to produce either elemental sulfur or sulfuric acid, both of which are readily marketable in Florida. This medium-Btu gas can be used as a hydrocarbon feedstock for producing pure H₂ and can also be combusted, similar to natural gas, in a combustion turbine for producing electrical power. In addition, depending on the particular gasification process used, the gas stream exits the gasifier at a temperature of about 2,500°F. It is possible to recover the thermal energy of this gas stream by means of a waste-heat boiler system. This system can then provide thermal energy for facility use or for steam to an IGCC power plant. The polygeneration technical concept is illustrated in the figure, "Polygeneration Concept." The plant block diagram is shown in the figure, "Polygeneration Plant Block Diagram."

Coal-gasification processes use either air, oxygen (O₂), or O₂-enriched air. Using O₂ in the gasification process has several advantages. It increases the Btu content of the output gas

stream, since the natural GN₂ content of air is not present to dilute the output gas. In addition, carrying the GN₂ would only serve to increase the quantity of output gas and would require downstream processing units to be oversized to handle the large gas stream. Additional processes would also have to be added to remove the GN₂ downstream in order to produce H₂ of the purity required. For these reasons, O₂ is provided by means of a cryogenic air-separation plant. In addition to providing O₂ for the coal-gasification process, large quantities of pure GN₂ are available as a byproduct from the air-separation plant, and this can be used at KSC to meet existing requirements for GN₂ purge. The air separation plant is also capable of providing propellant grade LO₂.

The medium-Btu gas stream coming from the gasifier can now be used both as a feedstock for making LH₂ and as a gas turbine fuel. Its composition will be primarily CO and H₂ with some carbon dioxide (CO₂). This composite gas is an excellent feedstock for making H₂ by means of the water (H₂O) shift reaction. The H₂O shift reaction in simplified form is as follows:



(Another concept would remove GH₂ directly from the gas stream by use of membrane-separation technology without the need for the shift reactor.)

The CO₂ can be separated and the H₂ purified by a number of commercial processes that leave a pure H₂ stream, which is fed to a standard H₂ liquefaction plant, and then pipelined or transported to the LH₂ storage tanks at Launch Complex 39, Pads A and B, for use by the Space Shuttle.

The medium-Btu gas, as mentioned earlier, also can be used directly as a gas turbine fuel. Use of medium-Btu gas in gas turbines is not common in the United States, but there is growing commercial experience. Existing off-the-shelf United States-designed gas turbines can use medium-Btu gas with relatively minor combustor modifications to accommodate higher mass flows and combustion temperatures. The high-temperature gas turbine exhaust can be used in a heat-recovery steam generator along with the steam generated by the gasifier waste-heat system to produce superheated steam. The superheated steam can be expanded through a steam turbine for producing electrical power. This arrangement is referred to as an IGCC power plant. Thermal energy from the steam cycle may also be used for facility heating and air-conditioning. The electricity produced in the IGCC plant can serve not only the large power needs of the air-separation plant and the LH₂ plant, but also part of all of the KSC and Cape Canaveral Air

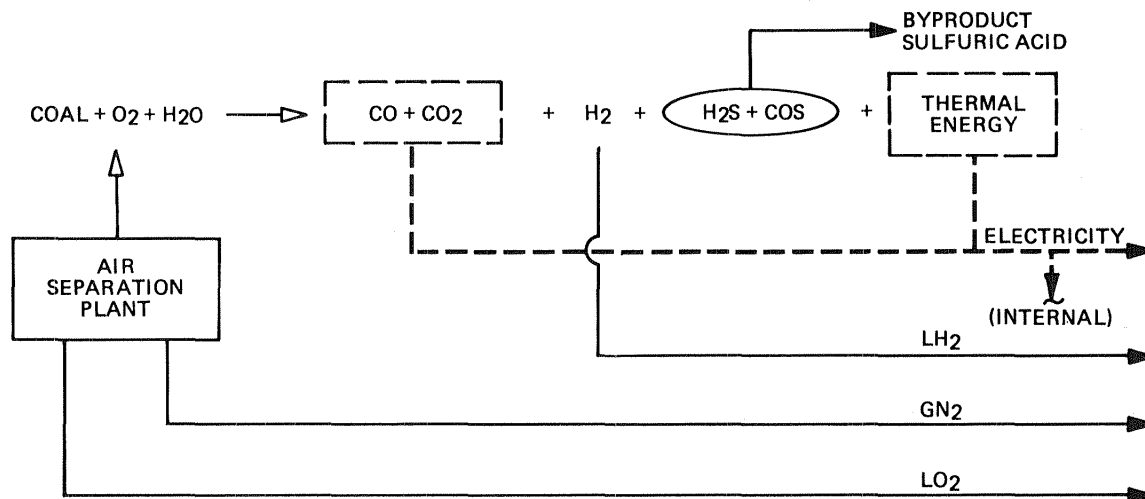
Force Station (CCAFS) facilities' power requirements.

The interrelated requirements of coal gasification, LH_2 production, GN_2 production, LO_2 production, electrical and thermal energy production, and KSC's unique need for these products naturally lead to an integrated polygeneration plant as described. The synergism inherent in this approach to LH_2 production, combined

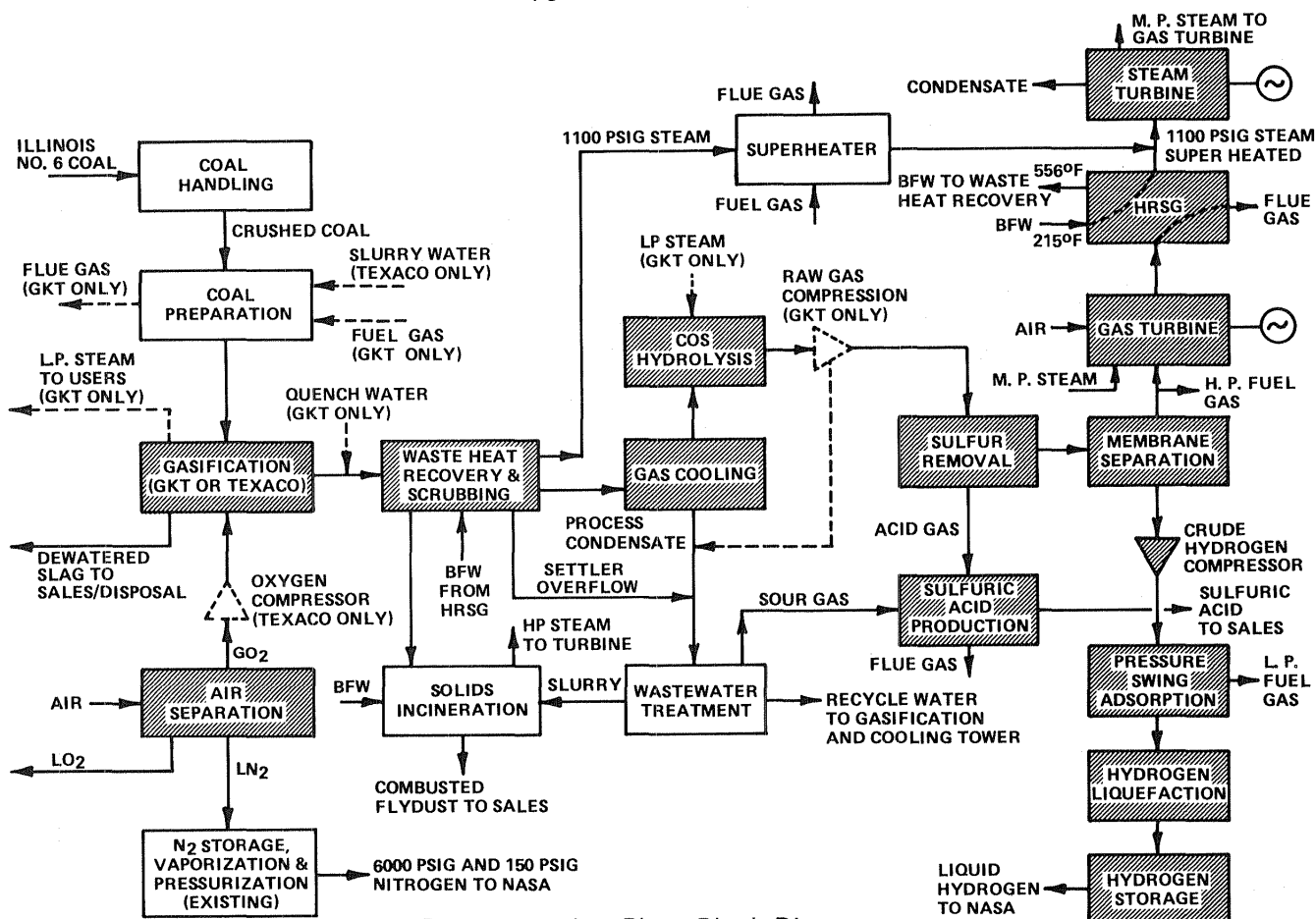
with IGCC power production and the lower cost of coal as a primary feedstock, provides a unique opportunity for reduction in the cost factor of producing LH_2 . This offers the potential for significant cost savings for KSC and the Space Shuttle Program.

L. Manfredi, 867-2196

DF-PEO



Polygeneration Concept



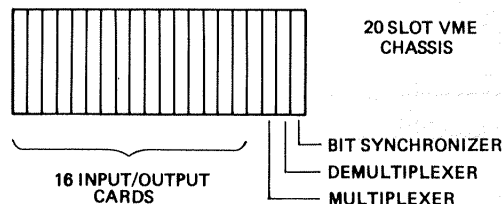
Polygeneration Plant Block Diagram

High-Speed Digital Multiplexer/Demultiplexer Development

Kennedy Space Center (KSC) is in the process of building a high-speed digital multiplexer/demultiplexer for transmitting low-speed data on fiber optic cable. An Engineering Development Unit (EDU) was built in 1984 under contract with Martin Marietta Corporation (MMC), to test the feasibility of multiplexing low-speed data into a high-speed data link. The multiplexer portion of the EDU consisted of pulse-code-modulation (pcm) input cards, burst input cards, and a multiplexer card. The multiplexer card is being designed to combine up to 16 pcm or burst input cards, which are interchangeable, into a 50 megabits per second (Mb/s) data stream. This 50 Mb/s data stream output then could be placed on fiber optic cable for transmission around KSC. The demultiplexer portion of the EDU consisted of a 50 Mb/s bit synchronizer card, pcm output cards, burst output cards, and a demultiplexer card. The demultiplexer receives the 50 Mb/s data and reassembles the 16 data streams on the output cards. Both the multiplexer and the demultiplexer sections of the EDU are contained in the same chassis to minimize cost, increase maintenance efficiency, and facilitate testing.

The MMC EDU met all design objectives in testing with no major problems in technical design. The pcm links were tested between 1 kilo-

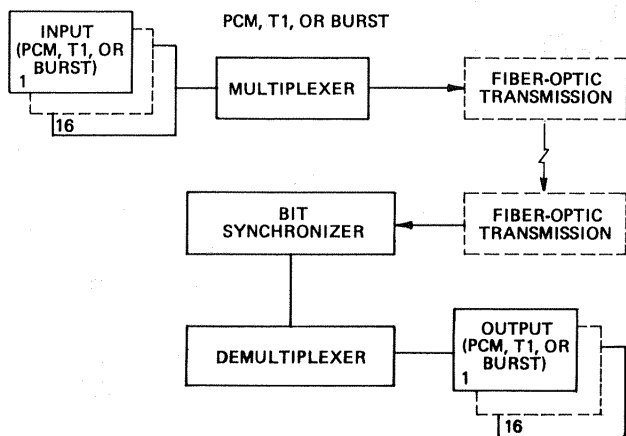
bits per second (Kb/s) and 2 Mb/s, and the burst link at 1 Mb/s. Up to three of the 16 possible links were multiplexed together at one time into a composite 50 Mb/s signal. Data jitter on the output links were measured at less than 50 nanoseconds for all frequencies tested.



Chassis Configuration of 50 Mb/s Multiplexer/Demultiplexer

MMC is now under contract to develop a preproduction unit in the third quarter of 1986. The preproduction unit will consist of all printed circuit cards packaged in an industry-standard VME rack with power supplies. An input/output card was added to the design of the multiplexer/demultiplexer unit to handle T1 data. T1 data is a standard communication link at 1.544 Mb/s that contains 24 channels of voice or data. This T1 data signal is used extensively at KSC and would be beneficial to add to the 50 Mb/s multiplexed data. A 20 percent design review of this unit was held with MMC in April 1985. Currently, all cards have been designed, and fabrication of the unit is in progress. MMC is scheduled to deliver the preproduction unit in April 1986.

Tom Herring, 867-3842
DL-DED-32



Block Diagram of 50 Mb/s Multiplexer/Demultiplexer

Local Processor Controlled Hardware Interface Module

The Hardware Interface Module (HIM) is an instrumentation multiplexer developed by NASA which provides an interface between the Space Shuttle ground-support equipment (GSE) and the Launch Processing System (LPS). The HIM was designed using CMOS technology for low power and high noise immunity. This interface consists

of commands or measurements of analog or discrete signal channels by one of several types of input/output (I/O) cards. Each HIM can be configured with up to 30 I/O cards which have four, eight, or 16 channels of electrically isolated interface to the GSE. Any measurement or command operation can be completed within 32 microsec.

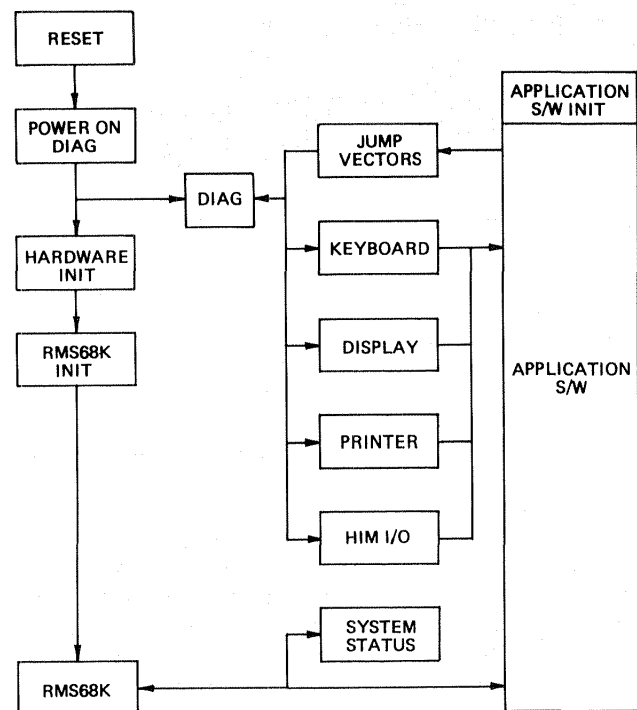
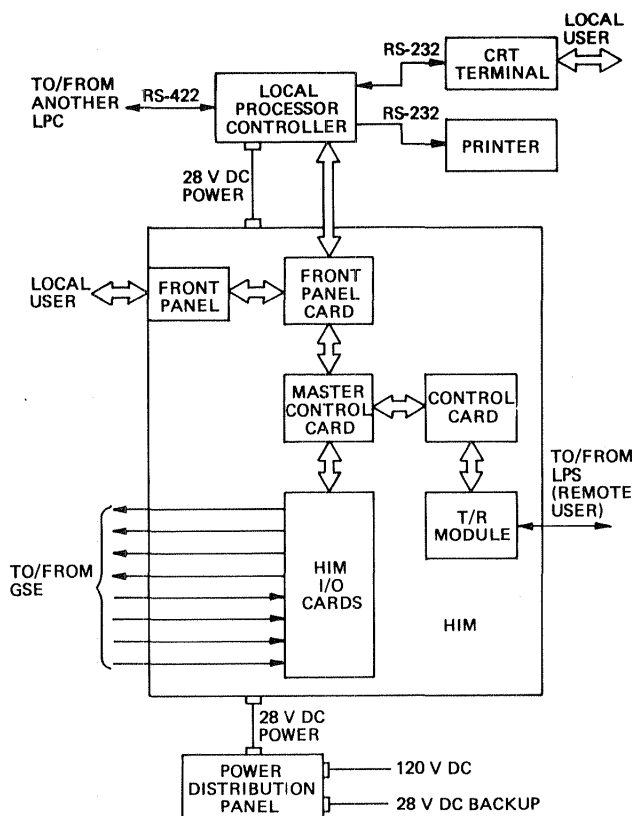
Communications between LPS and the HIM are over a 1 MHz Manchester encoded data bus similar to MIL-STD-1553. The HIM has no capabilities for processing or scanning the channel data present at the GSE I/O interfaces. All command and measurement cycles are in response to a request from the LPS to a specific data channel. Therefore, the HIM is dormant when the LPS is not operating, and the GSE must be placed in a local manual mode for operation.

In order to meet requirements for new GSE and facilities for the Space Shuttle and Space Station, an upgrade to the HIM has been implemented. The major goal of this upgrade is to provide a capability to the HIM which allows stand-alone automatic control of a system, without the LPS providing that control. Additionally, this upgraded capability cannot disrupt or interfere with communications between the LPS and HIM when the LPS is active. This required the addition of a Local Processor Controller (LPC) chassis to the HIM rack and the redesign of the HIM Master Controller Card (MCC) and front panel Control and Display Panel (CDP) card.

The LPC chassis consists of a power supply and a microprocessor card cage. DC power from the HIM chassis is supplied to a commercial 250-watt dc-to-dc power supply that provides +5 V dc and ± 12 V dc to the card cage. The industry standard (VME) microprocessor bus was selected for the card cage and cards. Selection of the VME was based on several factors. Rugged chassis construction and pin-in-socket connectors were considered important because of the vibration present during launches.

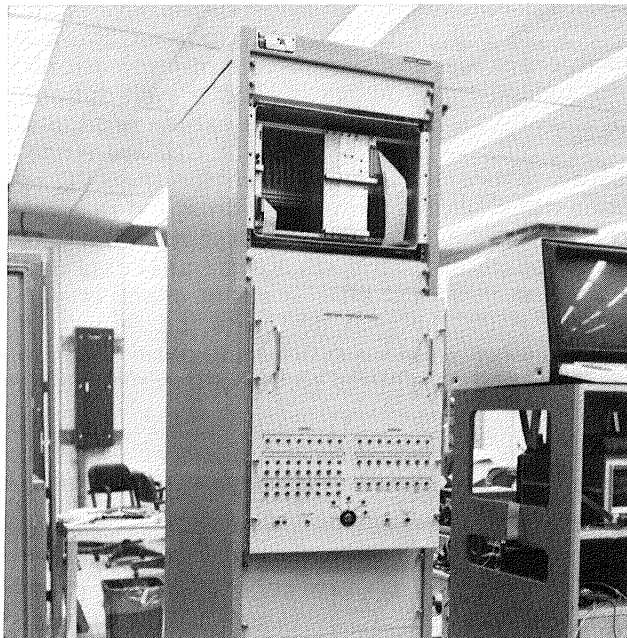
Other factors include the ability of the VME bus to allow multiple microprocessors to arbitrate for control of the bus in order to share memory and I/O resources. The bus allows for 8-, 16-, or 32-bit address and data buses, as well as providing a connector for user-defined interfaces. Acceptance and support of the VME standard have provided many commercial sources for microprocessor, memory, communications, and special function cards, and a well-defined specification for designing compatible products.

The redesigns of the MCC and CDP were necessary to provide an interface for the LPC to request the HIM to perform a command or measurement cycle. The CDP now accepts serial data from the LPC and converts it to parallel data that is sent to the MCC after a parity check is performed. After the HIM performs the requested cycle, the reply data is returned in parallel to the CDP and serially shifted to the LPC where parity is checked.



LPC HIM
Software Block Diagram

A requirement to allow both the LPS and LPC to communicate with the HIM at the same time meant that the MCC must arbitrate in order to prevent collisions which might corrupt the data. Because of LPS timing restrictions, the LPC cycles could not delay or impede any LPS request for a HIM cycle. Therefore, the MCC has new control logic which holds off or aborts an LPC cycle, in the event that LPS requests a HIM cycle be performed. New additional LPC status registers and communications registers were provided to allow the LPS and LPC to pass data back and forth. These new capabilities were added to address locations which were previously unused and are, therefore, transparent until the LPS software is changed to recognize them.



LPC-HIM Rack Configuration

The LPC chassis has been installed above the HIM chassis in order to avoid interference with GSE interface cables that enter from the bottom of the rack; also, it has been installed to take advantage of the air flow provided by fans on top of the HIM chassis. All LPC-unique hardware can be installed in the field so that existing HIM's may be upgraded to LPC HIM's, if the additional capabilities are required.

Several cards are provided with every LPC chassis as a standard complement of cards. The processor card contains a Motorola 68000 microprocessor, programmable timer, 16 Mhz clock, local Random Access Memory (RAM)/Read-Only Memory (ROM) and a RS-232C serial port. This serial port provides the interface for the local operator's terminal. The local RAM/ROM locations provide a monitor program which can be

called from the terminal by HIM technicians when troubleshooting a suspected LPC problem.

The LPC interface card design provides the interface between the HIM CDP and the VME bus. This card is the only NASA-designed custom card for the LPC VME chassis. A four-channel serial interface card provides two RS-232C ports, one of which is a spare and the other of which is used as a port for the local line printer. The remaining serial ports are configured for differential RS-422 communications between two or more LPC HIM's, utilizing the SDLC data protocol. Communications between LPC HIM's allow for redundancy, health checks, and shared resources in large applications which require multiple HIM's.

Memory for the LPC is provided on four VME cards. Two cards provide a total of 256k words of RAM. The remaining two cards provide for a total of 128k words of Programmable Read-Only Memory (PROM) for program storage. All programs used by the LPC are stored in PROM's, and no fixed or removable media are used because of the dust and vibrations that the HIM is subjected to. With the exception of the LPC interface card, all of the VME cards are easily substituted with cards from other vendors. Even with the card complement provided with an LPC, there are still 18 card slots available in the card cage. These remaining slots can be configured with additional memory, I/O ports, and multiple processors, to suit new applications.

Firmware for the LPC consists of four categories: an Operating System (OS), utilities, applications, and diagnostics. Selection of the OS was based on the requirement that it must be loadable into ROM. Motorola's OS Kernel RMS68K was selected, and provides facilities for task switching, activation queue, and a real-time clock.

The application program provides the control interface between the operator terminal and the HIM I/O channels. This program is unique to each GSE system that utilizes the LPC-HIM. However, many functions have become standard because of the similarities many systems have, regardless of specific applications. As part of the application program, colored CRT skeletons can be generated that are similar to the system skeletons on the LPS console. This is to prevent operator confusion when operating the system from either location.

Utility programs handle the I/O ports within the LPC; they do not have to be managed by the application program, so the programmers can concentrate on the applications. These programs are included for the printer, CRT, keyboard, and LPC-to-HIM and HIM-to-HIM communications interfaces. In order to utilize these programs, the applications program has to call and pass a parameter list to the utility, and continue. The utility program performs all of the low-level handshaking and formatting, and returns data or



LPC HIM Operator Consoles Showing Interactive System "Skeletons" Which Allow Cursor-Controlled Command Selection (Installed at Pad B)

a status to the applications program.

The diagnostic program is run whenever the HIM is powered up, or can be entered by command. Upon power-up, the LPC RAM/ROM interfaces are checked for proper operation before the MCC is exercised and the HIM cards roll-called and displayed. All the tests must be passed before control of the HIM is turned over to the application program for operation of the system. Additionally, diagnostics may be entered by operator command to aid in troubleshooting suspected problems.

The first system to use LPC HIM's is the Pad B Environmental Control System, which must provide air conditioning to the Space Shuttle 24 hr. a day when the launch vehicle is on the pad. Recently, LPC HIM's have been baselined for the Orbiter Maintenance and Refurbishment Facility (ORMF) and the Hazardous Artificial Intelligence (AI) into the Servicing Facility. Additional research is going on to add LPC as a means for providing GSE system control and expert diagnosis for the designers and operators.

R. A. Nelson, 867-3367

DL-DED-31

PROJECT REFERENCE DATA

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Hazardous Gas Detection System Sample Line Transport Time Study	W. Helms, P. J. Welch 867-4478 867-4614 DL-NED-31 DE-MAO-2	
Remote Sensing of Hydrazine	M. M. Scott, Jr., P. M. Rogers 867-3086 DL-DED-32	Jet Propulsion Laboratory
Advanced Hazardous Gas Detection System	J. D. Collins, W. Helms 867-4438 DL-NED-32	Naval Research Laboratory (J. Wyatt)
Hydrazine Personal Dosimetry	J. C. Travis, W. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose)
Evaluation of Hydrazine Detectors Based Upon Emerging Technology	J. C. Travis, W. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose)
Pattern Recognition Methods for Toxic Vapor Detection Using Microsensors	J. D. Collins, W. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose)
Remote Detection of the Burning GH ₂ Plume from the Shuttle Centaur Vent	J. C. Travis 867-4438 DL-NED-32	PRC (C. Mattson)
Optical Fiber Vortex Shedding Flowmeter	B. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)
Flowmetering — Using Vortex Shedding Instrumentation	B. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)
Gamma Ray Densitometer Liquid Level Instrumentation	B. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)
Liquid Characteristics Under Micro- Gravity Conditions	B. Howard 867-3366 DL-DED-31	University of Florida (Dr. E. Farber)
Fiber Optic Terminal Equipment Development	M. E. Padgett 867-3367 DL-NED-12A	Martin Marietta Corporation
Collapsible Air Lock	T. La Montagne 867-4454 SI-FSO-3	Burns & Roe Industrial Services Corporation (D. Hattchett)
Effectiveness of a Non-Recirculating Air Curtain on Contaminants Control	F. N. Lin 867-4156 DD-MED-1	

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Simulation of Steady Liquid-Vapor Flow Under O-G Using Immiscible, Neutrally Buoyant Droplets in Water	F. N. Lin 867-4156 DD-MED-1	University of Illinois
The Effects of Sense Line Length on Pressure Spike Measurements in Cryogenic Flow	K. Buehler 867-3332 DD-MED-43	
Magnetic Reliquefaction of Hydrogen	F. S. Howard 867-3202 DD-MED-4	Los Alamos National Laboratory
Rapid Prototyping Supports Space Station Operations Language Requirements and Concept Development	L. Wilhelm 867-7582 DL-DED-21	Planning Research Corporation (J. Jones, V. Lewis)
LPS Software Development Network — a New Approach to an Old Problem	J. Medlock 867-6213 SE-GDS-1	Lockheed Space Operations Company (L. Bradfield, R. Olson, J. Wilkinson)
Hydrazine Adsorber and Neutralizer	R. A. Gerron 867-4493 SF-ENG	Auburn University
Study of Coatings That Require Minimal Surface Preparation for Potential Application on LC-39 Structures	P. J. Welch 867-4614 DE-MAO-2	
Conductive Organic Polymers as Corrosion Control Coatings	C. J. Bryan 867-4614 DE-MAO-2	Los Alamos National Laboratory University of Pennsylvania
Evaluation of Sealants for Dissimilar Metal Corrosion Prevention	C. V. Moyers 867-4614 DE-MAO-2	
Accelerated Corrosion Test Methods for Zinc-Rich Coatings	C. W. Hoppesch 867-7051 DE-MAO	
Applicability of Acoustic Emission Monitoring to Pressure Vessel Testing	P. J. Welch 867-4614 DE-MAO-2	
Computer Tomography	J. W. Larson 867-2997 SI-PEI-3A	EG&G, Florida (J. H. Weiler)
Material Compatibility	J. C. Travis, W. Helms 867-4438 DL-NED-32	Naval Research Laboratory (S. Rose)
Robotics Application Development Laboratory (RADL)	L. Davis 867-3402 DD-NED-22	

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
Electrostatic Robotic Test Cell	H. M. Delgado 867-3367 DL-DED-31 R. M. Howard 867-3366 DL-DED-31 A. Pickar DL-DED-31	General Electric Robotics and Vision Systems
Meteorological and Range Safety Support System	J. R. Reynolds 867-4317 SF-SAF	ESMC/SEM Patrick Air Force Base ENSCO, Incorporated
Thunderstorm Currents	R. P. Wesenberg 867-4438 DL-NED-31	University of Arizona (Dr. P. Knider)
Clear Air-Wind Sensing Doppler Radar	R. P. Wesenberg 867-4438 DL-NED-31	Air Force Geophysics Laboratory
Improved Short-Term Forecasting of Lightning at KSC Based on Surface Wind Convergence	W. Jafferis 867-3997 SO	
Rocket-Triggered Lightning Program (RTLTP)	W. Jafferis 867-3997 SO	Air Force Aeronautical Laboratories Federal Aviation Administration Eastern Space and Missile Center University of Arizona University of Florida State University of New York Naval Research Laboratory AFWAL
Expert Planning and Scheduling Systems	J. Dumoulin 867-3466 CS-SED-21 J. M. Ragusa 867-7882 CS-SED K. Wetzel 867-3750 CS	MITRE Corporation (Dr. J. Katz) Georgia Tech (J. Gilmore)
Machine Learning and Control	E. E. New, M. Cornell 867-0797 SE-ETD-22 SE-ETD-21	
Controlled Environment Life Support System (CELSS) Breadboard Project	W. M. Knott 867-3152 MD-ENV	
Multispectral Analysis of Nuclear Magnetic Resonance (NMR) Imagery	R. L. Butterfield 867-3017 PT-TPO	University of Florida Washington University
PRACA-Based Prediction	J. R. Hankins 867-4493 SF-ENG	EG&G ENTEC Division

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION
KSC Avionics Test Set	M. O'Neal 867-6210 SE-GDS-23	McDonnell Douglas Technical Services Company (M. Calabrese, D. Headley, M. Gardner, E. Fillmore) University of Central Florida (G. Whitehouse, T. Hagood)
Voice Activated Computer Utilization	L. D. Fair, Jr. 867-7040 SI-CSD-2	
Simulation of the Space Station Logistic Module Turnaround Processing Flow	R. W. Tilley 867-4167 SS-OCO	
Documentation Management System	T. Mariana 867-4861 CS-CSO-1	
Technology Assessment for the Dynamic Resource Development/ Allocation Model for Spacecraft Processing	J. McBrearty 867-4646 SM-ANA	Knight Economics, Incorporated (Dr. J. Knight)
Conceptual Development of Polygeneration Advanced Liquid Hydrogen Transfer Line	F. S. Howard 867-3202 DD-MED-4	CVI, Incorporated
Heat Pipe Heat Exchanger Dehumidification Coupled to Solar Air Conditioner	W. H. Boggs 867-2133 DD-FED	Dinh Company, Florida Florida Solar Energy Center
Polygeneration	L. Manfredi 867-2196 DF-PEO	
High-Speed Digital Multiplexer/ Demultiplexer Development	T. Herring 867-3842 DL-DED-32	Martin Marietta Corporation
Local Processor Controlled Hardware Interface Module	R. A. Nelson 867-3367 DL-DED-31	Martin Marietta Corporation

STANDARD TITLE PAGE

1. Report No. NASA TM 83099		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Research and Technology 1985 Annual Report of the Kennedy Space Center				5. Report Date November 1985	
				6. Performing Organization Code PT-TPO	
7. Author(s)				8. Performing Organization Report No.	
9. Performing Organization Name and Address NASA John F. Kennedy Space Center Kennedy Space Center, Florida 32899				10. Work Unit No.	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546				13. Type of Report and Period Covered Technical Memorandum	
				14. Sponsoring Agency Code	
15. Abstract <p>As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safe, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to Space Station and other future programs. The Engineering Development Directorate encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1985 Annual Report. The report contains brief descriptions of research and technology projects in major areas of Kennedy Space Center's disciplinary expertise.</p> <p>For further technical information about the hprojects, contact David A. Springer, Project Engineering Office, DF-PEO, (305) 867-3035. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Centerwide research and technology program.</p>					
16. Key Words <p>Research and Technology</p>					
17. Bibliographic Control			18. Distribution <p>Unclassified — Unlimited Subject Category 99</p>		
19. Security Classif.(of this report) Unclassified		20. Security Classif.(of this page) Unclassified		21. No. of Pages 65	
				22. Price	

End of Document